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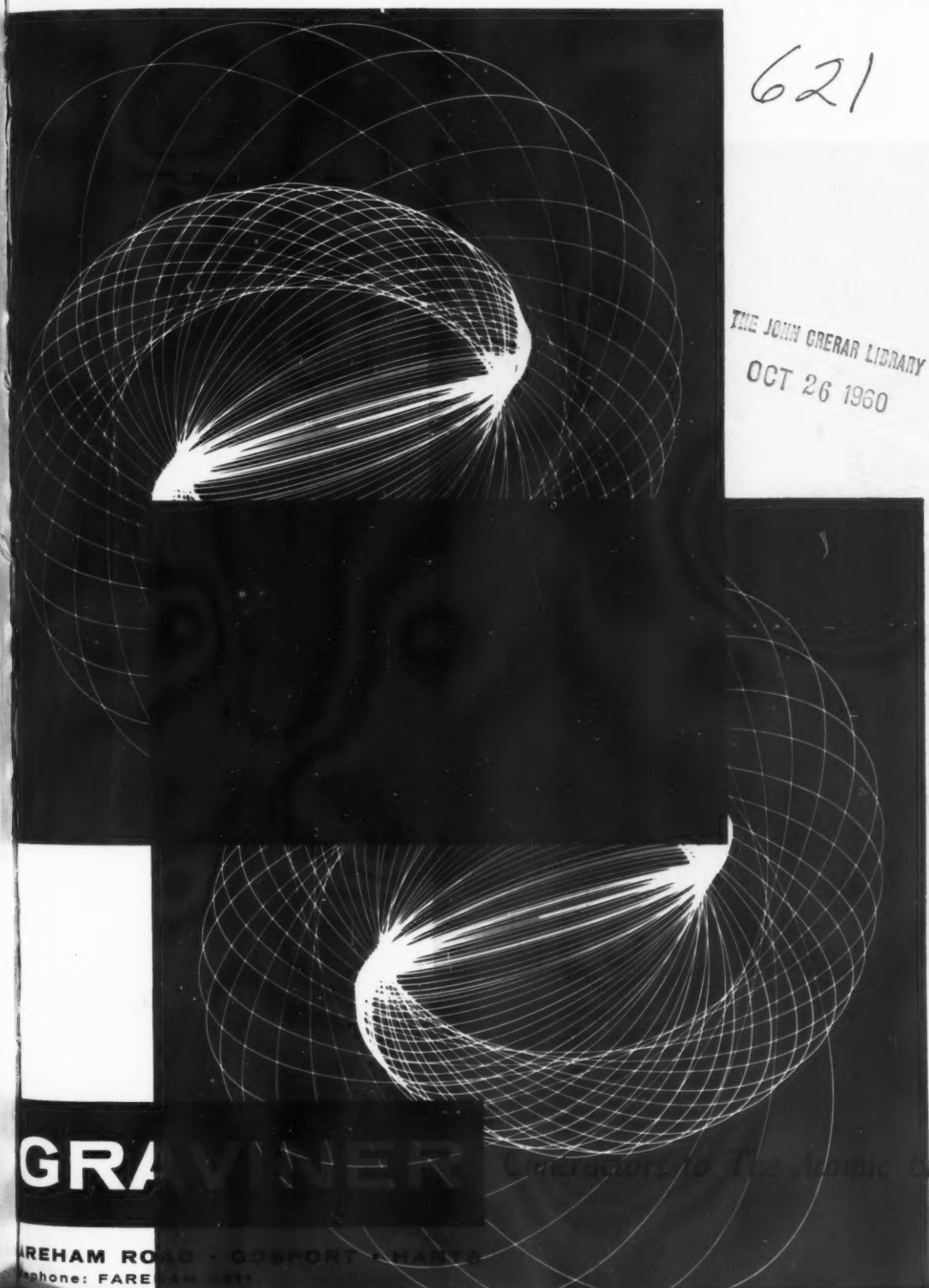

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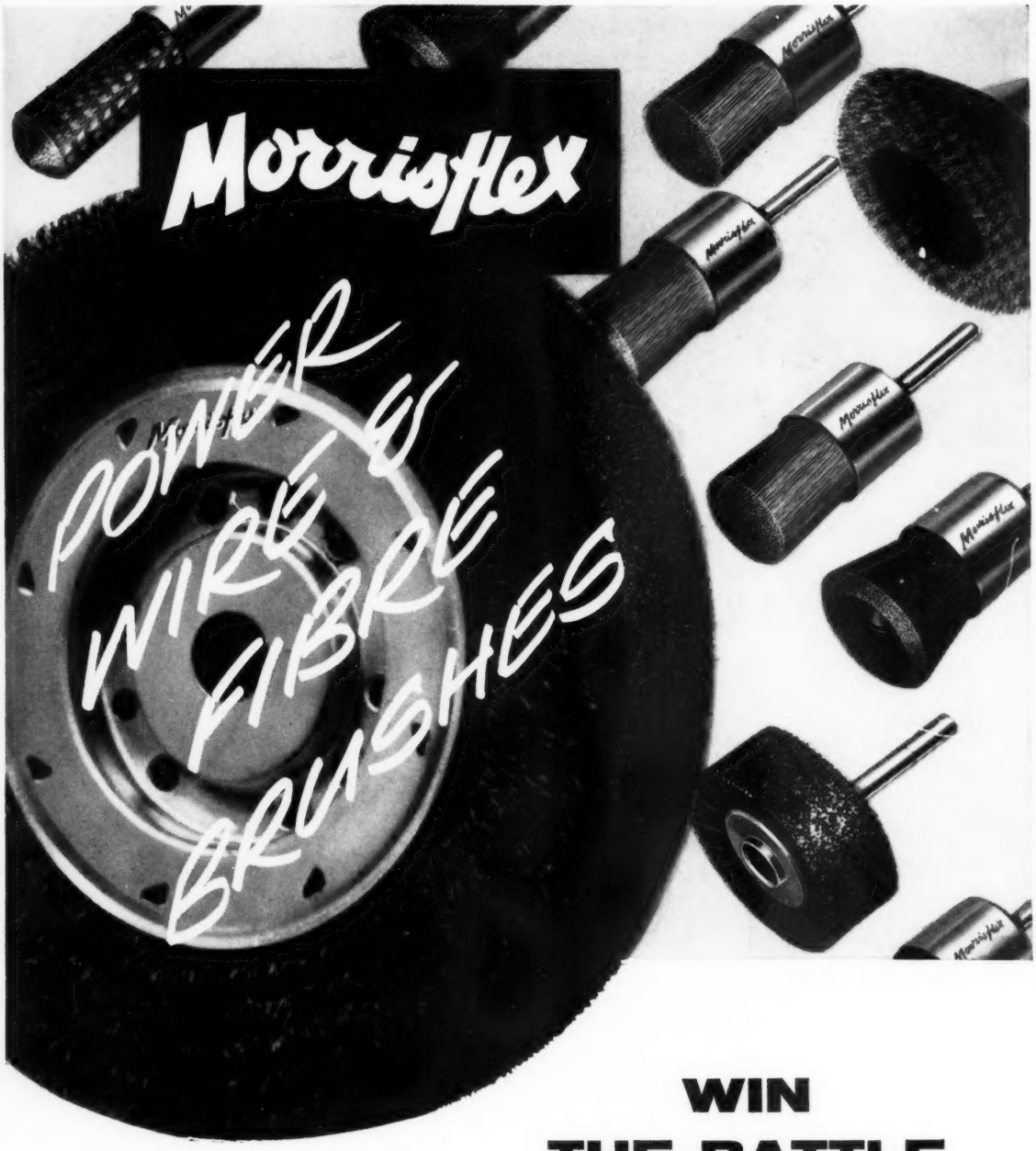

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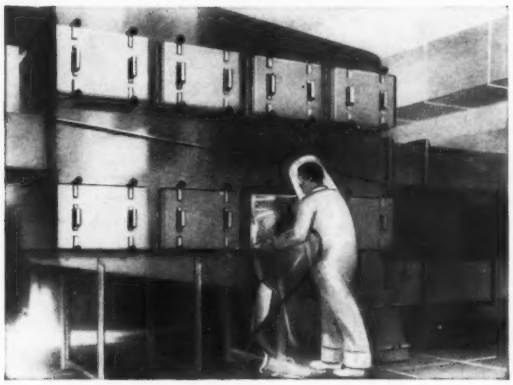

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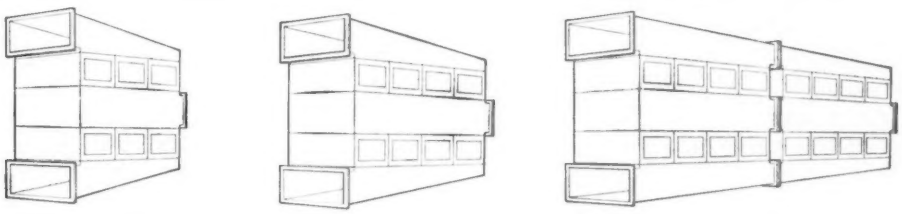

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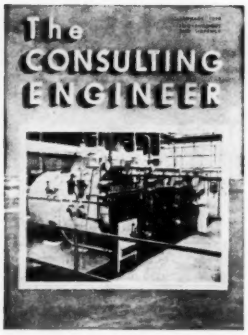

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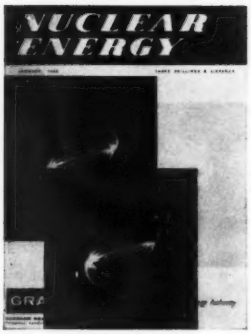

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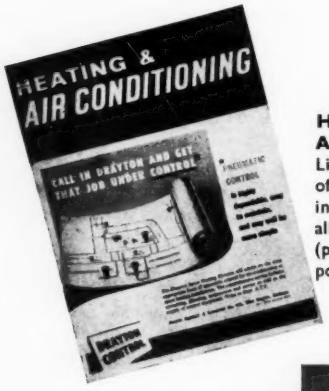

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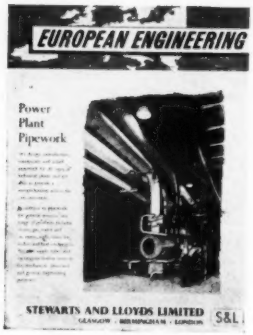

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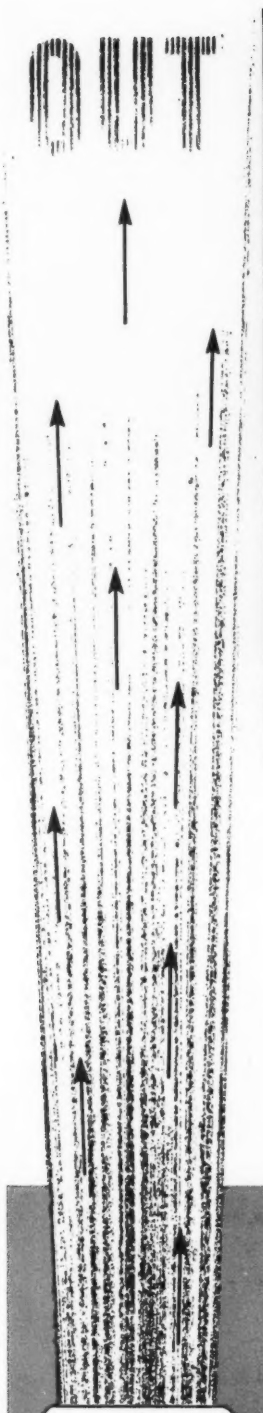

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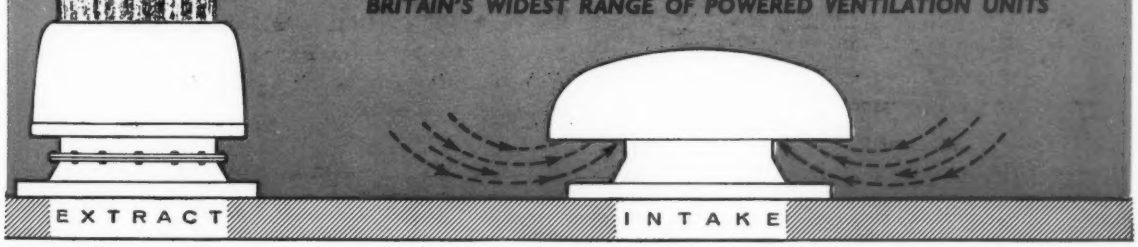

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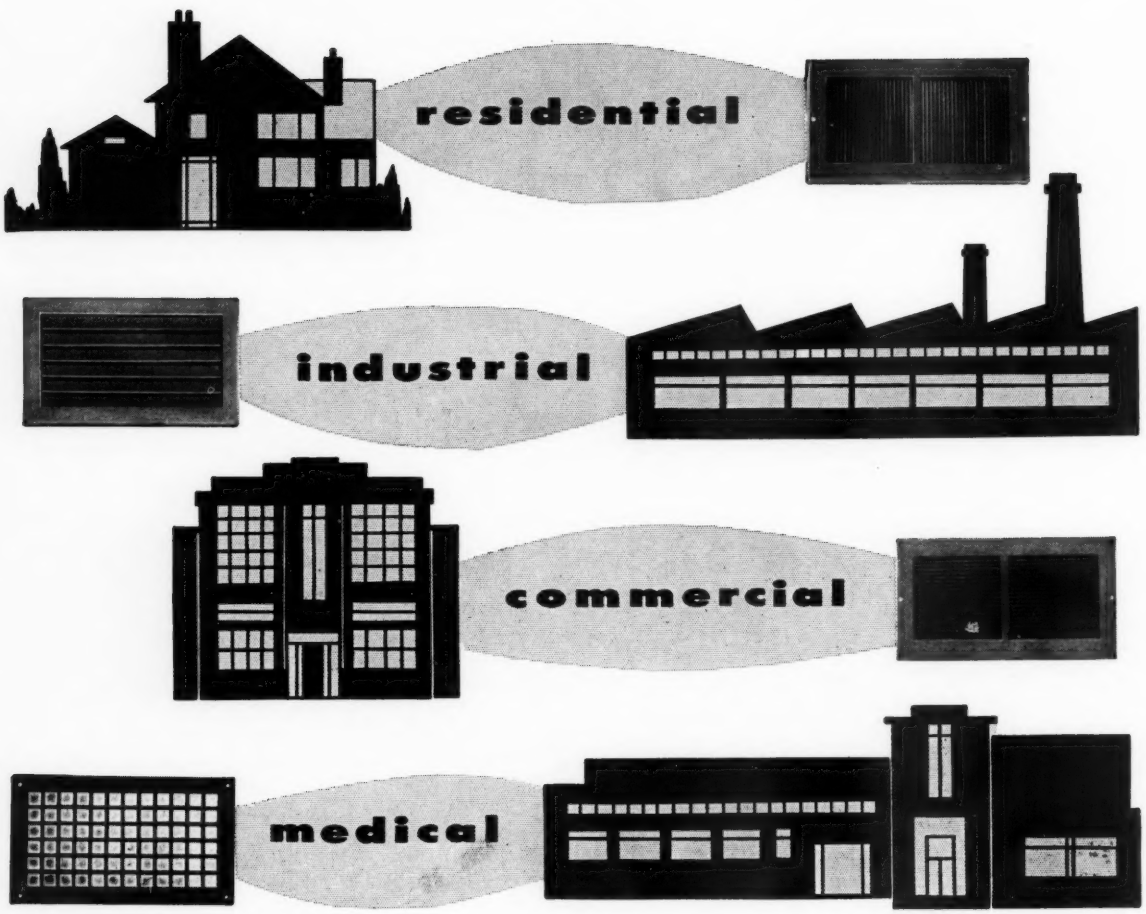

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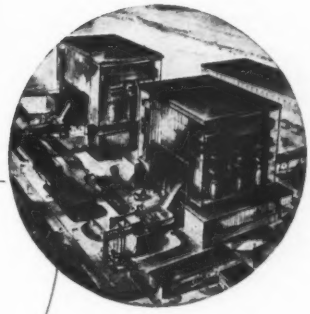

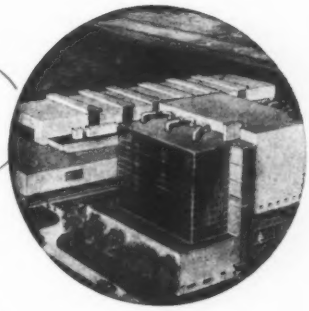

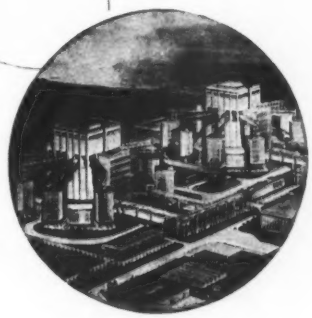

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Journal of the Institution of Nuclear Engineers

OCTOBER, 1960

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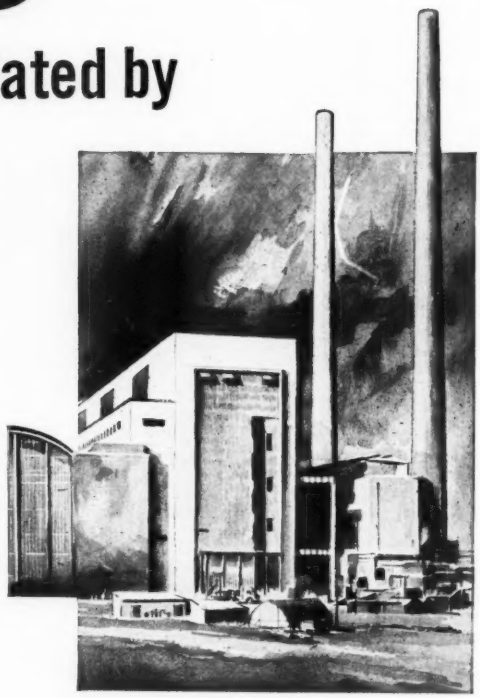

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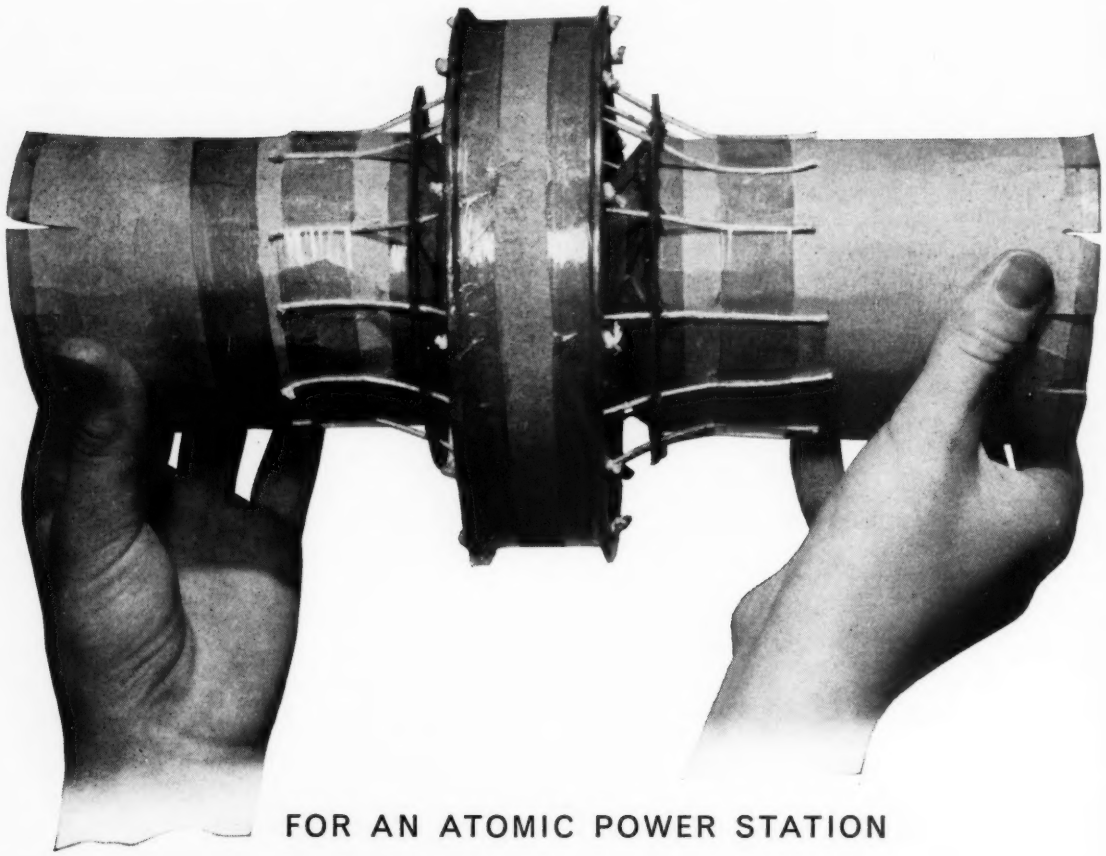
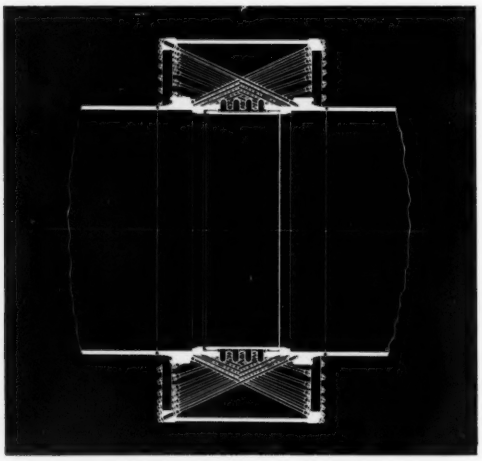


FOR AN ATOMIC POWER STATION



Don't despair if you cannot immediately follow the functioning of the bar system. It took the Engineering Division several days to understand it, and the only way they could make it clear to our executives was with the cardboard model in the photograph.

With cardboard, string, the office sticky-tape and an artificial pearl borrowed from a typist (for the spherical joint between the two cones) Richardsons Westgarth engineers have knocked up a radically new solution to a very old and tricky problem – how to take up the expansion of large pipes carrying high pressures. The problem came into the design office in the specific form of the CO_2 ducting of the Trawsfynydd Atomic Power Station. Pressure 265 p.s.i.; temperature 420°C; axial thrust on any cross section over 1,000,000 lb.

The usual means of taking this thrust – on either an internal flexible tongue or an external arrangement of hinge pins, guides and rollers – are cumbersome and, worse, flexible in only one plane, so that any sideways deflection produces stresses incapable of analysis. Rollers and pins need lubrication and are subject to wear, and both disturb the uniform distribution of stress around the periphery of the pipe. In the new Richardsons Westgarth joint the end restraint is provided by a ring of high-tensile steel bars, and flexing is taken entirely by elastic stress in these bars. The joint is thus flexible in *all* directions. No lubrication is needed; all forces are calculable – and they are fed uniformly onto the periphery of the restraint.

This is the kind of solution – unconventional, simpler, sounder and cheaper – that the fresh thinking of Richardsons Westgarth engineers is continually producing.

RICHARDSONS, WESTGARTH & CO LTD

The Controlling Company of the RICHARDSONS WESTGARTH GROUP Wallsend, Northumberland, and at 58 Victoria St., London, SW1
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RW 67

NUCLEAR ENERGY

COMMENT

THE case put before the United Nations General Assembly for a nuclear energy conference in 1962 on the same grand scale as those held in 1955 and 1958 was not based on reasoned argument. There is no justification for repeating the overblown affairs of the previous years. Both the 1955 and 1958 conferences served to present the world with information on a little known subject, and even at the latter event many of the papers were " old hat." To-day there is such a stream of specialized small conferences that anything new is quickly swallowed up and has little chance of surviving for presentation at a large, general conference.

The earlier conferences had also other purposes to serve. Up to 1955 atomic energy had been associated with war and death, and the world was still recovering from the effects of the 1939-45 holocaust. The wholesale revelation that nuclear energy had a bright side, too, brought some faith and hope for the future. It is true that the scientists probably waxed over-enthusiastically in their subject and painted the future in too-glowing colours, but their papers on the application of nuclear energy for peaceful purposes certainly provided a welcome boost to international morale.

Three years later it was decided to review world progress in this field and there is no doubt that the 1958 conference at Geneva served an extremely useful function in this respect. It also provided an opportunity for lowering the barriers of secrecy which had shrouded much of the work undertaken in this field, particularly in thermonuclear reactions—yet another boost to the world's morale.

Despite the huge success of the 1958 conference there was a general feeling amongst its participants that it was too big and unwieldy. There were too many papers, too much material to assimilate, and too many people. One of the most valuable functions of a conference is to enable scientists to meet and discuss their problems together. In this way not only are minds stimulated and new ideas created but also a feeling of unity of purpose achieved. But this can only happen under the appropriate conditions. If there are so many papers that there is little time to discuss them fully and so many delegates that everybody just cannot meet each other, with the result that the conference becomes highly impersonal and much of its value is destroyed. For this reason alone it would seem unwise to attempt to repeat the mammoth undertaking of 1958.

As has already been said the worth of the papers presented at a conference have to be considered. Even at the small specialized conferences a considerable amount of material is read which is of doubtful value, in the sense of being new. Even so, these conferences are small and manageable. The scientists they attract can have plenty of time to meet each other informally and thresh out their particular problems over the cup of tea or glass of vodka. In the financial world much important business is done over the dinner table; the same can be applied to the scientific world. More can often be learnt by the scientist over the coffee table than in the conference room. Obviously, large scale conferences at which general progress in the field are reviewed are of some value. It is important however that they are properly timed. 1962 is really too soon after 1958. A more appropriate year would be 1965. The United Nations could well note the example of the conveners of the World Power Conference, whose large-scale meetings are held once every six years.

If we are to be faced with a general conference on nuclear energy in 1962 then let the organizers ensure that it is kept to manageable proportions. The selection of papers, particularly when they cover such a vast subject, is, of course, difficult, and there is also the problem of keeping a proper balance between the contributions from different countries. The effort involved, could be well spent but the conference could also prove to be nothing but a waste of time, energy and money.

* * *

AS doyen of the nuclear energy research establishments Harwell remains unchallenged. The prestige of the centre soars high in the scientific firmament and there is rarely any hesitation on the part of scientists and engineers to work there. Yet it must be admitted that some of the glow and excitement of the early years at Harwell have somewhat dimmed. This is to be expected. Maturity has closed in and with it has come a little hardening of the exuberance with which the Harwell Establishment was at one time associated.

Strangely, little of this vital ingredient of the " pioneering spirit " appears to have been passed on to the Winfrith Atomic Energy Establishment, the largest of the " dominions " in the Atomic Energy Authority's Research Group " empire," synonyms so aptly used by Sir Basil Schonland, director of the Group, who himself is a Commonwealth man. Perhaps it is partly because everything at Winfrith is brand new, that there is not the atmosphere of a Harwell. Also contributory to this apparent deficiency is the spaciousness of its layout. And, of course, the establishment is not carrying out such fundamental work as its Berkshire parent, it is more of an industrial nature.

Despite surface appearances there is little doubt that much valuable work is in fact being undertaken and perhaps when the attractive, streamlined buildings have begun to wear and there are a few more reactors dotted around the site a more purposeful air of research will pervade. It is certainly an attractively situated centre in which to work and the technical facilities, together with the social amenities provided, are second to none. Though by-passing the exuberance of the early Harwell it has all the makings of eventually becoming a mature, well-established, important research centre.

Thermoelectric Direct Conversion in Nuclear Reactors

by W. E. Shoupp
Westinghouse Electric Corporation

As the search for more efficient power generation systems is extended two promising areas of technology are opened up:—(1) that of the temperature of the heat source; and (2) that of materials to withstand higher temperatures. The standard source of heat—chemical combustion—may take place at a variety of temperatures and rates. It may be slow—as in the rusting of iron; or very rapid—as in the exploding of dynamite. It does not necessarily involve oxygen for some metals will burn in nitrogen. In fact, some materials—such as hydrazine N_2H_4—may burn within themselves without the addition of combustion supporting substances.

From the rough scale of the combustion temperatures shown in Fig. 1, it can be seen that flame temperatures from 3,000°F. to 8,400°F. are possible. A survey of these higher temperature areas as heat sources for power generation discloses that as temperatures rise, materials problems become acute because materials that can operate in the upper temperature zone of the chart might have to be made from expensive and scarce raw materials. This would, of course, make such high temperature materials economically unattractive for conventional power generation. Similarly, many of the fuels needed for the higher flame temperatures may have required large amounts of power for their production and as a result, are also economically unattractive.

Points to Passive Method

The significance of Fig. 1 is that the number of possible usable materials decreases as the temperatures increase. More important is that as the temperatures increase, the types of materials that are suitable for high temperature use are not always suitable mechanically. Typical of materials that will withstand these higher temperatures are the ceramic type which are generally of low ductility and tensile strength. Therefore, if the higher temperatures for power generation are to be exploited the poor ductile and tensile characteristics of the ceramic type materials limit conversion consideration to static rather than dynamic systems. This suggests the passive type of power generating method such as thermoelectric, thermionic, or magnetohydrodynamic. Fortunately, this is a reasonable requirement as such materials are ideally suited to passive, high-temperature operation.

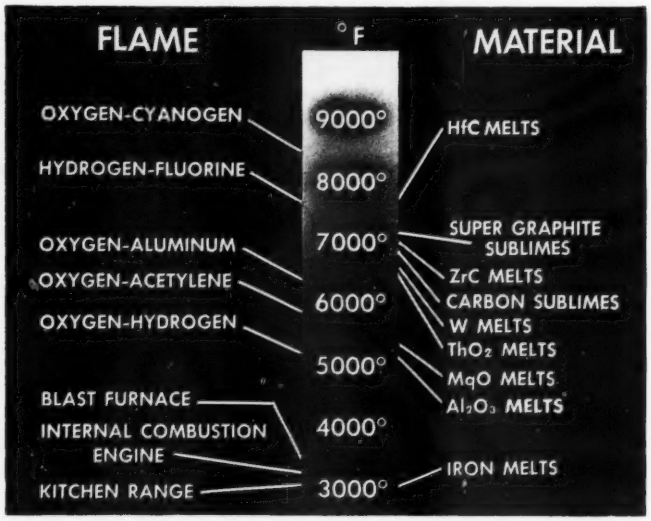


Fig. 1—Combustion temperatures of flames of several well-known gases and melting point of several well-known materials

Since the nuclear reactor is the prime example of a passive heat source—no moving parts—it is worth examining its high temperature possibilities. Outlet temperatures in most water reactor systems are in the 600°F. range. This does not mean that nuclear reactors are inherently low temperature devices because quite the opposite is true. But it does mean that since reactor development is still in the early stages, the materials or technology to take full advantage of the temperatures available have not been developed. But it is known that as temperatures go up, the increased capital cost and technical complexity that result can more than offset the gain in efficiency that the higher temperatures achieve. While these are problems of some magnitude today, both will eventually be solved, for only through their solution will the economics of these new methods of power generation be resolved.

How can the nuclear reactor help in this progress?

Element in Heat Source

The fission heat generator in a reactor is the fuel element, an accepted design for which is to encapsulate uranium oxide (UO_2) pellets in a tube of stainless steel or zirconium. Such a fuel element is shown in Fig. 2.

The fission process possesses energy equivalent to a temperature of about 100,000,000,000°F. From this it

can be seen that the fission process itself does not limit the reactor output temperature, which is, however, limited by the low heat conductivity of uranium oxide.

Fig. 2—One accepted design for a nuclear reactor fuel element: encapsulate uranium oxide (UO_2) pellets in a tube of stainless steel or zirconium

As shown in Fig. 3, the uranium oxide (UO_2) temperature in the fuel pellet centre is 4,150°F. which is reasonably close to its melting point of 5,000°F. Since uranium oxide has a low heat conductivity factor, a 75 per cent. drop in temperature is experienced as the heat is conducted from the centre of the pellet to the outside—from 4,150°F. down to 1,042°F. A second temperature drop brings the usable temperature down to 699°F. This comes about as follows: the uranium oxide pellets have a different coefficient of expansion than their encapsulating material. Therefore, since the pellets must be free to move within the tube, a gap between the pellet and the inside wall of the tube is designed into the fuel element. And this gap accounts for a temperature drop of 343°F. down to 699°F. A further drop of 21°F. is experienced as the heat is conducted through the wall of the cladding material. This brings the fuel element outer wall temperature down to 678°F. A final temperature drop of 149°F. takes place between the coolant water and the fuel element outer surface. This temperature drop—film drop, as it is called—reduces the hot channel water temperature to 603°F.

All Heat Not Used

Now the typical reactor has some regions, particularly near the outside edge—see Fig. 4—that are not as hot as the hottest channel. When this cooler water is mixed with the hottest, the average temperature in the plenum chamber above the reactor core is only 529°F. And this is the temperature at which it is used. It is apparent that though a very hot material—over 4,000°F.—is started with, efficient use is not made of the high temperature available.

The thermoelectric principle to convert directly the heat of fission into electrical energy can be used. The most efficient way to do this is to expose the hot junctions of the thermoelectric device to a hot fuel element of a nuclear reactor and the cold junctions to the moderator-coolant water. As can be imagined, a design poses a problem in the selection of materials for the thermoelectric device, for unless the materials behave properly under irradiation conditions in a reactor, they will not be suitable for thermoelectric devices. This places very stringent requirements on thermoelectric materials and reduces greatly their

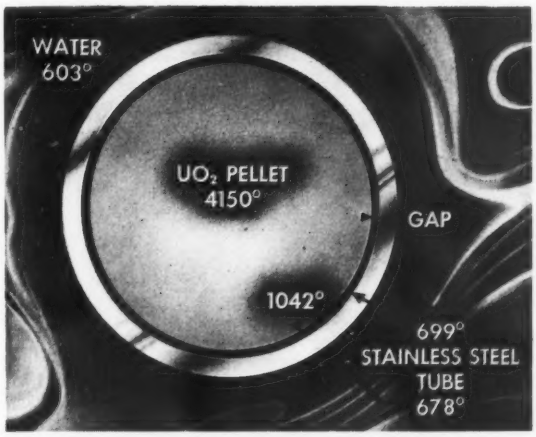


Fig. 3—Cross-section of a typical fuel element showing temperature loss from centre of uranium oxide pellet to the outer surface of encapsulating tube

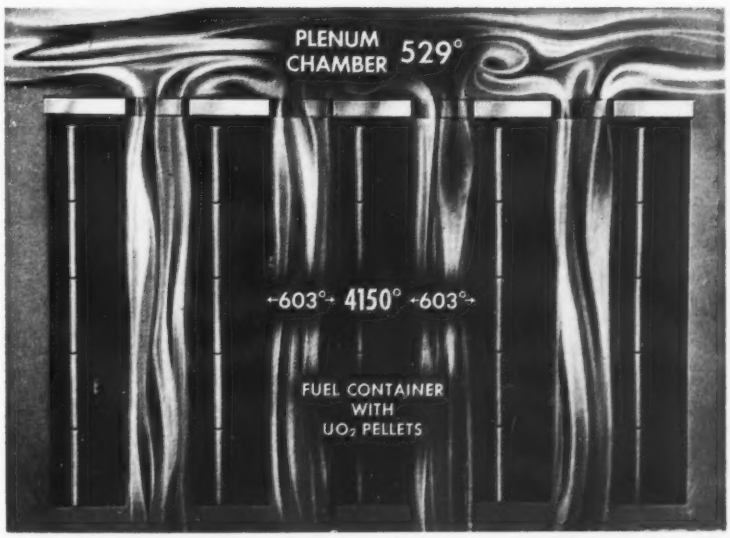


Fig. 4—Temperatures of coolant water in hot channels of reactor pressure vessel and in plenum chamber above reactor core

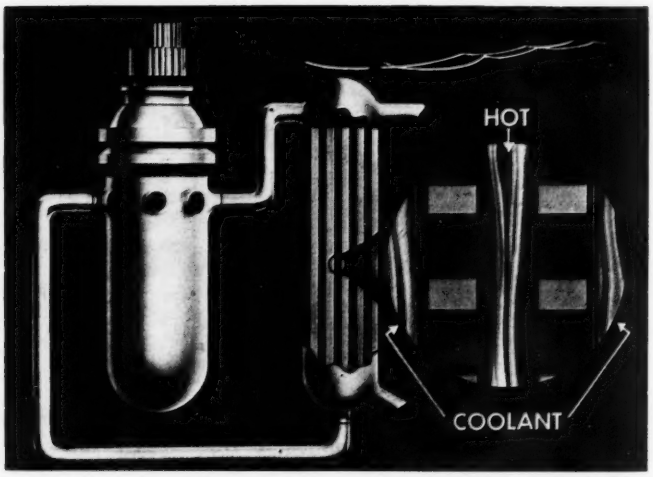


Fig. 5—Indirect type thermoelectric generator. Thermoelectric tube boiler connected to reactor pressure vessel. Heat from moderator-coolant water is converted directly to electrical energy by the thermoelectric device

availability. However, such materials are available and a number of them are being tested in the Westinghouse Testing Reactor at Waltz Mill, Pennsylvania.

To overcome the undesirable feature of radiation effects on thermoelectric materials, an indirect method can be employed and the moderator-coolant water used as heat source. This necessitates making a boiler with thermoelectric tubes instead of the regular boiler tubes and connecting it to the nuclear reactor pressure vessel as shown in Fig. 5.

The thermally hot, moderator-coolant water flows down the centre of the thermoelectric tube—shown in detail in the diagram—and heats the alternate hot thermocouple junction while the cooler secondary water flows around the outer surface of the thermoelectric tubes and cools the alternate cold thermocouple junction and in so doing develops the required temperature difference. The direct-current electric power generated is then distributed and used as direct current power, or is changed to alternating-current power. The heat source for a thermoelectric generator of this design can be a radioisotope or fossil fuel as well as a nuclear reactor.

Direct over 10 kW

Westinghouse believe a thermoelectric generator of the indirect type to be practical in the 1w to 10 kW size. In fact, models of them in this power output range are being built.

For thermoelectric generators above 10 kW in size, Westinghouse studies indicate that the indirect type becomes cumbersome and inefficient. It appears, therefore, that the direct type, where the thermoelectric elements surround the nuclear fuel (Fig. 6)—will be superior.

Finding Combination

Although the direct-type thermoelectric generator appears most feasible for the larger sized power generators, there are problems to be solved. One involves the thermoelectric materials. It is not possible to have a single good hot junction and a single good cold junction material that will operate efficiently over a wide temperature range. Most thermoelectric materials possess favourable thermoelectric characteristics

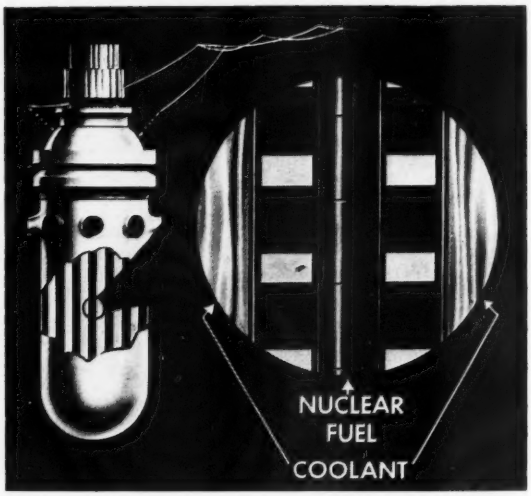


Fig. 6—Direct type thermoelectric generator. Thermoelectric elements are wrapped around nuclear fuel elements. Heat from fission is converted directly to electrical energy by the thermoelectric device

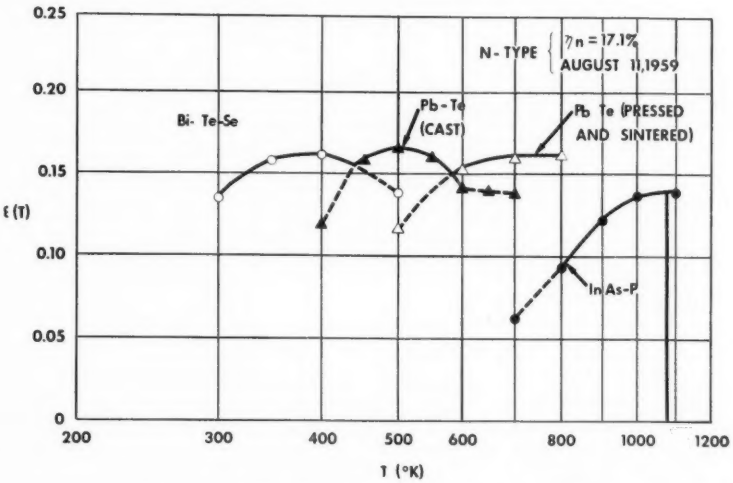


Fig. 7—A typical group of thermoelectric materials possessing desirable characteristics for the hot junction of a thermocouple

over only a limited temperature range. Therefore, to cover the complete range of temperature available, it is necessary to select a group of materials that possess good thermoelectric characteristics over specific temperature bands and connect these electrically in series.

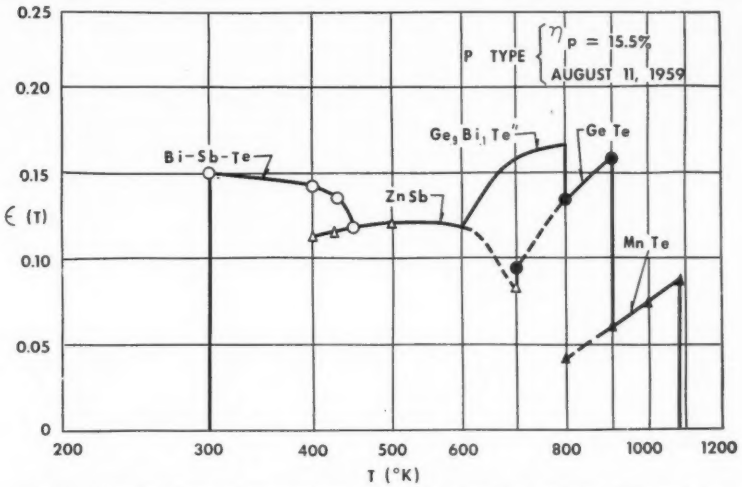


Fig. 8—A typical group of thermoelectric materials possessing desirable characteristics for the cold junction of a thermocouple

A typical group of materials that would be suitable for one junction is shown in Fig. 7, while another group of materials that would be suitable for the other junction is shown in Fig. 8. It is indeed a difficult problem to find such a variety of materials for normal thermoelectric operating conditions, but when the radioactive aspect is added, the problem becomes a major challenge.

Elements in Series

So far more has been said about fuel elements than about nuclear reactors as a heat source. One point about thermoelectric junctions not mentioned is the fact that each one only generates a fraction of a volt. Therefore, to make electric power available at usable levels of voltage, a great many of these junctions must be connected electrically in series. This cascading operation is greatly simplified by the fact that reactors have many fuel elements, and, as shown in Fig. 9, these can be connected electrically in series to produce reasonably high levels of voltage. The individual fuel elements may be fabricated as shown in Fig. 6.

A different way of generating power statically is the thermionic method. The principle involved is relatively simple. Heat is applied to an electron emitting filament and the thermal energy extracted from the heat converted directly into electrical energy. The filament heat source may be electric power or fission heat. A power generator built on this principle at the Atomic Energy Commission's Los Alamos, New Mexico, Scientific Laboratory has been operated for short periods. The hot junction of such a " gas thermocouple " or thermionic device is a heated filament which must be an electron emitting surface. But there is no reason why the heat source could not be an atomic reactor.

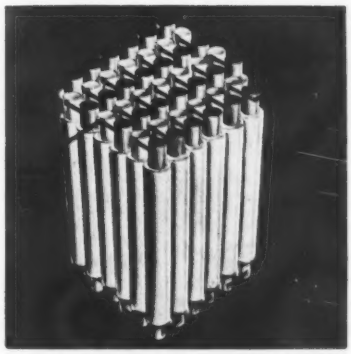


Fig. 9—Suggested arrangement of combination nuclear fuel elements and thermoelectric devices to produce usable levels of voltage

In summary, on a long term basis, it is believed that direct conversion of fission energy through thermoelectric and thermionic generation can become a reality for simple passive systems operating at high temperatures. The realization of this objective depends upon reactor development, and again, on the ability to develop high temperature structural and thermoelectric materials. The nuclear reactor offers an ideal source for magnetohydrodynamic and other direct conversion methods.

U.K.A.E.A. Monographs

Some Preliminary Measurements of the Tritium and Carbon-14 Content of the Stratosphere over England, by F. R. Barclay, M. J. W. Elliott, P. Goldsmith, J. V. Jelley and A. R. Osborne. Published by AERE, Harwell. Ref. AERE—R 3271. Available from H.M. Stationery Office. Price 2*s.* 6*d.*

Precision Distillation Columns, by W. Kuhn, translated from the German by R. Todd. Published by AERE, Harwell. Ref. AERE—Trans 850. Available at Harwell Library.

Kinetic Theory of an Ionized Gas, Part 2, by W. Marshall. Published by AERE, Harwell. Ref. AERE—T/R 2352. Available from H.M. Stationery Office. Price 7*s.* 0*d.*

Neutron Flux Measurements on an Aluminium Panel, in the Pool and in a Natural Uranium Graphite Stack on Lido, by E. D. Jones. Published by AERE, Harwell. Ref. AERE—M 608. Available from H.M. Stationery Office. Price 4*s.* 0*d.*

Deuteron Triple-Scattering Experiments, by R. J. N. Phillips. Published by AERE, Harwell. Ref. AERE—R 3306. Available from H.M. Stationery Office. Price 2*s.* 6*d.*

Average Electron Energy in Beta Decay, by M. F. James, B. G. Steel and J. S. Story. Published by AERE, Harwell. Ref. AERE—M 640. Available from H.M. Stationery Office. Price 3*s.* 0*d.*

A Compact Multiple-Stirring Apparatus, by W. H. Thornett. Published by AERE, Harwell. Ref. AERE—M 643. Available from H.M. Stationery Office. Price 1*s.* 9*d.*

The Radioactivity of the Atmosphere Near Ground Level Due to Distant Nuclear Test Explosions, by D. H. Peirson, R. N. Crooks and E. M. R. Fisher. Published by AERE, Harwell. Ref. AERE—M 620. Available from H.M. Stationery Office. Price 1*s.* 9*d.*

An Invariant Approach to Equilibrium Plasma Discharges, by J. Sparrow. Published by AERE, Harwell. Ref. AERE—R 3301. Available from H.M. Stationery Office. Price 4*s.* 6*d.*

Design and Engineering Problems of the Spent Fuel Element Irradiation Ponds at AERE, Harwell, by J. W. Mark. Published by AERE, Harwell. Ref. AERE—R 3391. Available from H.M. Stationery Office. Price 7*s.* 0*d.*

An Experimental Study of Electrodeionization and its Application to the Treatment of Radioactive Wastes, by D. C. Sammon and R. E. Watts. Published by AERE, Harwell. Ref. AERE—R 3137. Available from H.M. Stationery Office. Price 7*s.* 0*d.*

Resonance Absorption in Heterogeneous Systems, by G. Memmert. Translated from German by E. L. Poole. Published by AERE, Harwell. Ref. AERE—Trans 853.

INSTITUTION OF NUCLEAR ENGINEERS

100 GN. AWARD FOR PAPER

AN award of 100 guineas is to be made to the author of the Inaugural Paper to be read at the Annual General Meeting of the Institution of Nuclear Engineers on December 9th. This was decided at the meeting of the General Council on September 8th.

It is understood that papers on any aspect of nuclear energy submitted by members of the Institution will be considered for the award. Entries will be judged by a technical committee to be appointed by the Council.

Sir John M. Duncanson, president of the Institution, was expected to make a fuller statement about the award at the Inaugural Dinner at the Savoy Hotel, London, on October 3rd.

Dinner Guests

Reviewing the plans for this dinner, the president confirmed that Sir Alexander Fleck, KBE, DSc, former chairman of ICI Ltd., would be the principal speaker, Sir Eric Harrison, KCVO, the Australian High Commissioner in London, would also speak. Among other distinguished guests at the dinner would be The Rt. Hon, Lord Mills, The Rt. Hon. Peter Thorneycroft, the Austrian, French and German Ambassadors, Mr. C. Bartlett, Sir William Robson Brown, Sir John Erskine, Mr. W. K. Hutchinson (President of the Institution of Chemical Engineers), Sir Dennis Proctor, Air Vice Marshal Sir Victor Tait, Sir Vincent Tewson, Mr. Isaac Wolfson, and others.

The Council approved the engagement of the Royal Artillery band to play during the dinner.

"Teaching Aids" Project

Dr. F. R. Paulsen submitted a report on progress made in the "Teaching Aids" project, the purpose of which is to obtain information on the use of visual and other aids for the teaching of nuclear subjects and publish it in book form. Dr. Paulsen said that considerable interest had been shown in the project and he had received valuable material from many schools, universities, colleges, institutions and other organizations interested in teaching.

Of particular help had been contributions from personnel at Argonne National Laboratory, U.S.A.; Darmstadt Technische Hochschule, Germany; the Isotope School, Wantage; Royal Military College, Shrivenham; Massachusetts Institute of Technology; University of New South Wales; Société d'Applications Industrielles de la Physisique, France; Nuclear-Chicago Corporation; Harvard University; Institute of Paper Chemistry, Wisconsin; Instituto Biologico, Brazil; Stratford High School, Connecticut; Oak Ridge National Laboratoty; Kerntechnik, Germany; Berkeley University, U.S.A.; and Amarillo College, Mexico. Dr. Paulsen had also received contributions from many individuals, especially in Germany; and help and suggestions had been promised from the University of Arizona, the Imperial College of Science and Technology, Royal Institute of Technology, Stockholm, and Borough Polytechnic, London.

Lecture Slides

A suggestion had been received from Dr. Weigel, of Germany, that the Institution might build up a collection of coloured slides on nuclear subjects that might be used to illustrate lectures. He offered to loan his own collection to enable the Institution to make copies.

Commenting on the interest shown in the project by Mr. Maitland-Edwards, Staff Inspector of the Ministry of Education, Dr. Paulsen said that it might be fruitful to discuss the matter with him. As the Institution hoped one day to become an examining body it might prove a beneficial contact.

Membership Certificate

The Council approved the design of the Certificate of Membership and the secretary was instructed to have a quarto-size die-stamp made.

Apologies for absence from the September meeting were received from Mr. Everett, Mr. Merrin, and Dr. Jenkins, all of whom were on holiday.

NEW MEMBERS

R. O. Barratt, JM
Lewes, Sussex.

R. Beattie, A
Crawley, Sussex.

I. G. Blellock, M
Widnes, Lancs.

A. Broadbent, M
Egremont, Cumberland.

G. Bugo, M
Swanley, Kent.

N. Cenci, M
London.

F. W. Coyle, M
London.

G. M. Cracknell, A
Borrowash, Derby.

J. Fray, M
Annan,
Dumfriesshire.

T. B. Gardner, JM
Castle Bromwich.

R. R. Goddard, M
Harwell,
Berks.

A. J. H. Goddard, M
London.

W. J. L. Holt, A
Blackheath, London.

J. D. Judge, A
Chislehurst, Kent.

J. Kelly, A
Abingdon, Berks.

D. Kitson, A
Latchingdon, Essex.

J. Lewins, M
Meysey Hampton, Glos.

N. A. McLeod, A
Loughborough, Leics.

P. A. L. Northcott, M
Hornchurch, Essex.

J. K. Platt, JM
Erdington, Birmingham.

E. A. Roberts, M
Barrow-in-Furness,
Lancs.

E. L. Robson, M
Holmrook,
Cumberland.

K. Sankson, M
Dursley, Glos.

R. J. B. Slinn, M
Didcot, Berks.

G. P. Stannard, A
Derby.

S. C. Smith, M
Shrivenham, Wilts.

D. T. Turnbull, M
Newcastle-upon-Tyne.

Ronald Wakelam, M
Wolverhampton.

W. G. A. Walters, A
Richmond, Surrey.

A Look at the Radioactive Substances Act

by Peter Lewis—Our Parliamentary Correspondent

IN 1956, the Minister of Housing, showing commendable foresight, asked for a panel to be set up to determine future requirements for the control and disposal of radioactive waste. At that time, with the exception of the UKAEA, radioactive waste could be treated as ordinary waste products and one law governed the two. The panel felt that some pretty convincing evidence should be presented by those wishing to use radioactive materials, especially in view of the genetic effects resulting from irradiation. While the panel was quite aware that everyone suffered from natural irradiation, and that there would be a certain amount from radioactive waste, they saw no reason why the latter could not be reduced to a safe level.

There was some concern about the lack of precautions being shown at the time, in the use of radionuclides and gave as an example, luminizing rooms which they knew to be badly contaminated through inadequate precautions.

Aims for Disposal

In the White Paper containing the panel's report, they summarized their aims for waste disposal as follows:

(*a*) To ensure irrespective of cost, that no member of the public receive more than 0.03r weekly, *i.e.*, one-tenth ICRP level, for occupational workers.

(*b*) To ensure irrespective of cost, that the whole population of the country shall not receive an average dose of more than 1r per person in thirty years, and

(*c*) To do what is reasonably practicable to reduce the doses far below these levels.

The panels suggested methods of control, and the powers that should be given to the controlling authority form the basis of the Radioactive Substances Act which was made law in the middle of 1960, less than a year after the publication of the panel's report.

As a literary offering the Act, like any legalistic document, is tortuous and at times bewildering. However, it is now very clear that to possess radioactive substances from which waste may arise requires adherence to certain formalities, the first being an application for registration. It must be pointed out that in most cases the UKAEA and premises governed by a nuclear site licence do not come under the Act. When applying for registration the premises must be stated and the purpose for which they are to be used, together with full details of the radioactive materials that are to be employed and how they will be used.

The application may be returned with certain limitations and conditions attached—for instance, structural alterations to the buildings and modifications to apparatus. Any proposed movement of radioactive materials must be stated and containers will have to carry correct markings.

Mobile Units Covered

The Act covers the registration of mobile radioactive apparatus, including that used for testing, measuring or investigating materials which are outside the premises of those applying.

The disposal of waste requires authorization from the Minister, and without such authorization it is illegal to dispose not only of known radioactive waste but waste that is suspect. Such authorization is not required apparently in the case of clocks and watches. Whether this can be read as the production of clocks and watches is not made clear.

The following is what the Act considers to constitute "Accumulation" of radioactive waste:—"Where radioactive material is produced, kept or used on any premises, and any substance arising from the production, keeping or use of that material is accumulated in a part of the premises appropriated for the purpose, and is retained there for a period of not less than three months, shall, unless proved to the contrary, be presumed to be radioactive waste accumulated on the premises with a view to subsequent disposal." Thus the Act leaves no room for doubt and no margin for error.

Before anyone is given authorization to get rid of waste, the Minister and the Minister of Agriculture and Fisheries, will both consult any authorities they feel would be affected. In the case of inadequate disposal facilities being available, the Minister can supply them and make a corresponding charge. Before any refusal of registration or authorization by the Minister, a person may put his case to the Minister or his representative.

To see that the Act is enforced, inspectors may be appointed who will be able to enter a premises at any reasonable time and carry out tests and ask for information. If of course, you choose to ignore the Act you could, on summary conviction, be fined up to £100 and detained in the local jail for up to three months or both. On conviction on indictment you may well be placed behind bars for five years. It seems most unlikely that anyone should be unaware that he is handling radioactive materials and, in this day and age, would not be taking suitable precautions against contamination, but it does happen apparently, as with the case of the luminizing rooms. It would appear that the probability of illegal disposal of radioactive waste would be just as high, but how this is to be put over to Atomic Powers letting off nuclear bombs at odd intervals is not covered by the Act or even apparently by a lapel badge.

The Act provides definitions of radioactive material, waste and mobile apparatus. Radioactive material is defined as a substance possessing radioactivity which is wholly or partly attributable to a process of nuclear fission or other process of subjecting a substance to bombardment by neutrons or to ionizating radiations, not being a process occurring in the course of nature, or in consequence of the disposal of radioactive wastes or by way of contamination in the course of the application of a process to some other substance. There is also a table for helping in the assessment of the radioactivity of certain elements.

The Act is available from H.M. Stationery Office, price 1*s.* 6*d.*

RADIATION SAFETY AND CONTROL—III

PROBLEMS OF CONTAMINATION HAZARDS

THE PROVISION OF NECESSARY SAFEGUARDS

by A. R. Gould

Royal Military College of Science

The use of " open sources " of radioactive materials will necessarily involve the possibility of the attendant hazards of contamination in addition to the external " radiation " hazards referred to in earlier articles. Whenever these hazards are introduced—for purposes of a production programme, for experimental and inspection purposes or for research investigations, for instance—there is an obligation of radiological safety. The provision of the necessary staff, instrumentation and facilities to ensure radiological safety should be considered before the work begins together with the requirements for a special site or modifications to existing buildings and plant.

RADIOACTIVE work is usually carried out in buildings separated from non-active plant, such as offices, stores, canteens and other ancillary buildings. In ideal conditions this " active " area can be reached through only one entrance at which clothing change, monitoring and cleansing facilities are provided. The " active " area is itself divided up into " low level " and " high level " sections. The former comprises radiographic darkrooms, electronic workshops, health physics laboratories, counting laboratories and some inspection and chemical assay facilities and the latter, areas in which excessive levels of activity or contamination exist. Ideally each section should have separate access to the main entrance, with the low level section possibly being adjacent to the entrance.

Buildings and laboratories designed for " active " work contain the minimum of fittings and handles to be touched by hand. Where possible push doors, foot-operated taps, controls and switches are fitted. To prevent the harbouring of dust the joints between walls, ceilings and floors are concave and windows are without ledges.

Concrete Floors Lino Covered

Large exposed areas should be made corrosion-resistant, non-absorbent, and easily decontaminated. It is a good idea for the floors, which are recommended to be of concrete, to be covered with linoleum or other similar material which is then waxed or otherwise suitably treated. Minor contaminations can then be easily removed by taking off the wax, while after long usage or a dangerous spill the lino can be removed. Such a " strippable skin " technique can be applied to benches and other working surfaces.

According to the degree of probable contamination and processes involved, air control is installed, with " high velocity extract " for airborne contaminants. Fume cupboards, hoods and extract funnels should give a minimum linear air flow of 150 $\pm$50 ft/min in the operating position, while for the higher levels of the most hazardous materials rather specialized " glove-boxes " and even " frogman areas " may be required.

Radiation hygiene is, of course, most easily practised in buildings specially built for the purpose and where contamination is controlled by cleanliness, " good housekeeping" and limitation. Production techniques and plant layout should be aimed at minimizing the spread of active material and the production of dusts, sprays and fumes.

Consider Clothing

High standards of " cleanliness and tidiness " in clothes and in working areas should be encouraged. The need to limit personal exposure by means of protective clothing and shieldings should be implanted in the minds of the operators. Again, suitable training, when necessary, will have to be given in the disciplines of decontamination, cleansing, changing and dressing procedures.

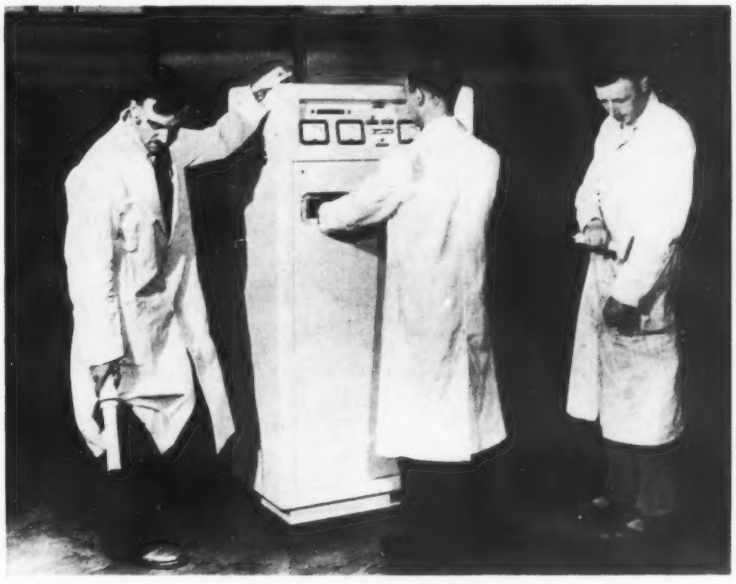
Toxic and corrosive chemicals or pyrophoric and explosive materials require especially strict control in an active area and attention must be paid to possible electrical, mechanical and other conventional industrial hazards. The use of emergency equipment—breathing apparatus, fire control, electrical isolators, gas controls and ventilation control—should be regularly practised to ensure personnel are completely familiar with the routine necessary in an emergency.

Exposures Checked

Where only " sealed sources " are used or a " radiation " hazard exists then periodic checks of the environmental hazards are usually sufficient to ensure that no serious exposure can occur. This satisfactory situation is further checked by the continual recording of the individual's external radiation dose as indicated by film badge and dosimeter.

Adequate exposure records for external radiation can be assessed by means of film badges and dosimeters—a practice now well established. By this means a continuous check is readily kept on each individual's dose throughout working hours. Unfortunately, it is only recently that any attempt has been made to assess and record in the same comprehensive manner the exposure of the individual to contamination.

The more serious nature of the contamination hazard has always been acknowledged and this apparent paradox of less safety effort being expended on the greater danger is only partly explained by difficulties of the more complex instrumentation required. The implementation of effective safety with these hazards has depended upon the establishment of procedures for radiation hygiene, and experience has shown that the main factor in safe working with open sources is always the provision of adequate staff to maintain cleanliness and to carry out the necessary health physics surveys and monitoring checks.



Hand and clothing monitor made by EMI Electronics Ltd. This instrument can check a person's hands simultaneously for alpha and beta contamination and at the same time monitor the clothing of two other people. Counting time for the hand monitoring is five seconds. Two independent probes are used for monitoring clothing

Background Needed

The greater significance given to environmental control and checks is emphasized by the relatively restricted application of checks for individual exposure by internally deposited radioactive materials. Except with a few specialist materials, individual exposures due to contamination, inhalation and ingestion at near-background levels can only be computed by individual application of environmental data. The weekly or monthly dosage to an individual may only be assessed from known details of the individual's duties and contact with active materials and apparatus, from details of his working hours and from his personal habits of behaviour and radiation hygiene, together with the relevant environmental data for that period.

Portable contamination monitor made by EMI Electronics Ltd. Using dual phosphor techniques with special circuits it is possible to monitor alpha and beta particles simultaneously

Technological advances in the application of detection techniques have shown that it is quite possible with available equipment to obtain useful indication of levels of exposure to these hazards.

At Least Once a Year

Even where sealed sources are used there should be a periodic contamination check of the environment which should be arranged whenever convenient slack periods occur, and in any case at least annually. This will require that all sources of radiation be completely removed from the site, or sufficiently shielded, to reduce any emitted radiation to below natural background levels and to avoid false alarms on sensitive contamination monitors. In other establishments where "open sources" are used or active material processed, and in which there is a very real continual risk of contamination, then daily routine survey checks should be made—even though only a partial coverage is possible. If an adequate health physics effort is not available then surveys must be concentrated on regular monitoring of the most suspect areas and a systematic coverage of the remaining areas in rotation.

Before "probe surveys" for fixed contamination are carried out, it is a good idea to make "smear checks" —even after cleaning or scrubbing of areas or equipment—to ensure that no "removable" contamination remains. A "smear check" is made by rubbing a filter paper circle over a sq.ft or so of the area investigated and then presenting the paper to a counter. If α emitters are suspected, the paper must be quite flat and uncrumpled, and must be placed within 2-3 mm of the detector face, without contamination of this face.

Rubber Former Design

It has been found[11] that a satisfactory paper former is made from a rubber bung (rationalized No. 49) over which a 2 in. internal diameter brass ring will retain a 9 cm circle of Whatman No. 544. This paper is toughened to resist tears even when wet, and has minimum ash if further radiological investigation, other than

a simple smear test, requires incineration and chemical ingestion of the contents. With these rubber formers a flat uncrumpled surface is available to smear flat surfaces of benches, walls, floors, etc., with even pressure. Practical experiments have shown that from three to ten times more activity is removed than is taken up by the usual 5 cm circle pressed down by two fingertips. Also, more consistent results are obtained.

Probe Survey Follow Up

Follow-up of the smear check is the probe survey. This is to determine the total amount of radiation emitted from a surface, which is usually expressed as equivalent to disintegrations/min/sq.ft of the isotope deposited on the *surface*, *i.e.*, with no appreciable self-absorption.

This survey gives no indication of the total amount present, which may in fact be some hundreds of times the equivalent activity (if the isotope emits α particles or weak βs) due to an absorption of the radiation by the surface contaminated. This is especially true of porous or absorbing surfaces such as wood, rubber, plastic and some metal oxides. Thus it can be seen that the interpretation of probe surveys is always subject to many complex factors.

In order to establish suitable interpretation techniques it is quite practical to contaminate representative samples of surfaces uniformly, by carefully calibrated aliquots of known activity, simulating actual operational circumstances under controlled conditions. In this way each type of probe may be calibrated for the sources in use, and comparison with some more conveniently reproducible standard will enable routine periodic checks on the equipment response to be maintained.

Realistic Factors

For example, in the author's laboratory, as a calibration of a Geiger probe to monitor clothing for a certain β emitter, actual areas of material from the type of garments in use were separately contaminated, some by contact and others by solution. Each area was used to calibrate the probe before and after laundering and in this way realistic probe factors were determined and a sound basis to the interpretation of probe surveys carried out on personnel and on laundry established. The actual amount of activity after laundering could, of course, only be determined by subsequent chemical ingestion of the samples and careful radiological investigation. These experiments provided a practical calibration for distributed contamination within the material, such as eventually occurs in actual use after many cycles of wear and laundering.

Such simple reproduction of operational conditions under precise control yields data that is extremely valuable as an operational guide to the problems of interpretation in radiation safety.

Air Sampling Necessary

Where any potential inhalation hazard is present, ideally there ought to be at least one continuous air sampling unit in operation in a representative breathing position whenever the hazard area is occupied by personnel. The ingestion and inhalation of active material is in general more hazardous than the external radiation monitored by the individual film badge. However, the inhalation exposures of individuals can only be calculated from practical observation of individual habits and hours worked, in relation to the activities recorded by these air sampling units.

Where the isotope is one of the most hazardous with a relatively minute body burden of some fractional microcuries, such as radium-226 used as an open source, then routine continuous air monitors must be supplemented by a portable air sampling unit. These are usually based on a modified vacuum cleaner which is equipped with an indicator of volume sampled through an appropriate filter paper.

The filter papers from the routine continuous monitors may be measured at periods over several days to allow for the decay of the natural radon and thoron disintegration products which are always present in air to a varying degree. Various electronic systems of crude α spectrometry have been tried in order to discriminate against these natural activities, but some recent developments[12,13,14,15] promise an effective compensation in order to achieve a rapid interpretation. If subsequent development can bring a simple application of these principles, then perhaps health physicists will be able to increase their efforts to monitor air activity sufficiently to record the individual's exposure to this hazard, which has been so neglected in the past.

Cautious Approach

More specifically, however, the spot checks made by portable samplers will increase in value and be of application to a larger number of isotopes than at present. This will in particular apply to the majority of α emitters, for at present the most commonly used $\beta\gamma$ emitters in medical applications are already detected in a few minutes at sampling rates of 200 to 500 litres/min.

The philosophy of hand and skin contamination in the United Kingdom was originally a cautious one in the absence of any significant experience, and based upon the most sensitive counters then available. The original hand monitors of some ten or so years ago were based upon air-proportional counters for α detection and designed in a much drier climate for wartime projects. Their sensitivity was such that positive detection of some 300 disintegrations/min/hand was readily obtained. Difficulties of humid climate and unstable electronics were countered in later models by decreasing sensitivity to 600 and then 2,400 D/min.

Effect of Raising Levels

Quite contrary to all other health physics levels in recent years this hand contamination level was successively raised, and different forms of arithmetic computations devised, to show justification for the use of less sensitive instruments.

The β hand monitors were originally motorized Geiger "scanners" which were later modified to simple static counters. Now available on the markets are such instruments as the large area scintillation counter using a special dual phosphor technique which is claimed to monitor both α and β simultaneously in a very short time.

Each of the relaxations in the contamination levels has, of course, enabled administrators to justify the decrease of the inconvenience of "long" counting periods (half a minute!!) to a few seconds.

Unfortunately the most hazardous ingestion danger is from alpha and low-energy beta emitters. With these, the presence of ordinary skin oils, perspiration and dust will give

factors of ten, hundreds and even, in many circumstances, up to a thousand in absorption. Any detected activity is only a "minimum-indicated activity" and the contamination should be recorded as in excess of this minimum. Obviously, in the practical circumstances of daily monitoring it is not possible to form any satisfactory estimate of the actual quantity on the skin. All that can be attempted is the detection of contamination by the most sensitive detectors in a reasonable half-minute count, and to ensure that all operatives scrub and dry their hands thoroughly whenever they leave the area and before monitoring. Such a system will ensure that no long-term repetition of detectable contamination can be transferred by the individual to his home or to other non-active areas of the establishment.

No theoretical computation which can allow for the variety of contamination circumstances that occur in practice is possible and no hand or skin monitor can be devised which will assess the total amount of alpha activity on a person's skin. The major armament of health physics in this difficult situation is that of strict radiation hygiene, control of the environment and the maintenance of continual vigilance by each exposed individual.

Conclusion

From what has been said in this article it is hoped that it will be appreciated that to cope with contamination hazards specialized buildings, apparatus and techniques are required. If individual exposures are to be limited to low levels the health physics responsibility for environmental checks must be backed by a high standard of discipline in radiation hygiene. Further, it is vital that unnecessary exposures should be avoided.

The assessment of radioactive material bodily ingested will be dealt with next month. The author will also discuss the role of the health physicist.

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BOOK REVIEWS

Atomphysik in der Schule, by Wilfried Kuhn. Published by Georg Westermann Verlag, Braunschweig, Germany. Size 6¼ in. × 9 in. × 320 pp. Price 26.80 DM.

Teachers of physics, like those in other rapidly-developing sciences, are constantly at their wits'-end to compress an ever-growing array of modern progress into a curriculum already packed with older classical work. This is a real problem, and one which must be faced. Herr Kuhn does not, in this book, try to solve this problem. What he does is to design a fascinating and coherent course in atomic physics, presented in a logical sequence, and embodying theoretical and experimental aspects of the subject, linked in an attractive way with classical physics. A book of this type must be judged from two aspects. Firstly, is it technically correct and well-presented? Secondly, is it suited for the objective which the writer had in mind? Let us consider the first of these aspects. The historical introduction is followed by a section on statistics and atomistics, and by the fourth chapter we are concerned with the nucleus, spin and magnetic moment, Cloud- and ionization-chambers, and various counting devices. Then follows a description of accelerators, cosmic rays, radioactivity, nuclear structure, mass defect, and binding energy. All this leads logically, of course, to nuclear energy, the uses of isotopes, atomic weapons, fall-out, radiation hazards, health physics, and dosimetry. The final section deals with a number of philosophical aspects. The theme is developed smoothly, and makes very interesting reading. There are over 150 illustrations, both diagrammatic and photographic. Generally, these are very clear and well-chosen, though some could, with advantage, have been larger. There are some technical faults, however. The crystal lattice models in Fig. 23 are not very convincing, especially that of the hexagonal lattice. Fig. 22 could have been more accurately labelled "diffraction diagram," rather than "spectrum," and some mention should have been made of the fact that the film had been wrapped around the wall of a circular camera. The author is quite incorrect in assuming that the value "2.69×10^{19} molecules/cc" is called in English the "Avogadro Number." This term is, in fact, used for 6.02×10^{23} atoms/g.atom, to which the name "Loschmidt Number" is applied in this book. Again, although there are many excellent diagrams of apparatus for various experimental determinations, they are somewhat inadequately described. It is remarkable, in a book of this type, to find no reference to the work of J. J. Thomson, although credit has been given to the originators of most techniques described in the volume. The material which the author has used is excellent, and it is well-presented, the book being pleasing to the eye, and good to read. Illustrations of educational equipment prove that Herr Kuhn had in mind the necessity for bringing the nuclear world closer to the pupil. Yet, I feel, he has not come close enough. It is difficult to believe that school-youngsters can cope with Maxwell's equation for energy distribution, Heisenberg's matrix mechanics, Schrödinger equations, Lorentz transformation and contraction, and Heisenberg's uncertainty principle. Either German mathematics teachers are singularly successful, or the word "Schule" has been envisaged as having a much wider significance than is normally understood. I feel that this book is an excellent one, but that it has been directed towards a readership which cannot make full use of it. Perhaps the pioneering work which Herr Kuhn has undertaken will be followed up.

F. R. PAULSEN

Power from Atoms, by Egon Larsen. Published by Frederick Muller Ltd, London. Size 5 in. × 7½ in. × 142 pp. Price 9*s.* 6*d.*

Mr. Larsen has an infectious enthusiasm for his subject and this account of nuclear energy and its various applications will immediately appeal to the imagination of the young reader with any bent towards science. Particularly exciting to the imaginative mind are the descriptions of the nuclear propelled aircraft that continuously circle the earth towing conventional planes behind and dropping these off when convenient. Another excursion into the future is provided by the reference to the photon rocket. Unfortunately, the author lets his enthusiasm and imagination get the better of him even for the more down to earth aspects of nuclear energy, with a consequence that some of his information tends to be misleading. It is surely possible to write accurately at the same time as being exciting. The book is illustrated with both half tones and line drawings. Most of them have been seen before and it would seem the publishers have missed an opportunity in not producing, say, some drawings showing how a photon rocket might look like or even work.

T.R.

* * *

The OEEC European Nuclear Energy Agency has recently published a new edition of its "Catalogue of Courses on Nuclear Energy in OEEC countries." This catalogue covering the 1960-1961 academic session, gives details of training courses in subjects relating to nuclear energy in some 170 Western European universities, technical high schools and research centres. It is designed to help science and engineering students who wish to acquire a better knowledge of nuclear subjects to find out what training facilities are available. Copies of the catalogue can be obtained on application to the OEEC European Nuclear Energy Agency, 38, boulevard Suchet, Paris, 16e.

Containment Vessels for Belgian Reactors BR II and BR III

Part II

by G. Herzet, P. Laval and G. Martelée
Cockerill-Ougrée

(*Continued from page 420*)

CONDITIONS under which the BR II containment vessel, described last month, were as follows:—

(i) Maximum internal over-pressure of 14.18 lb/sq.in. gauge, made up as follows:—

0.675 lb/sq.in. resulting from a possible drop in the atmospheric pressure while the reservoir is isolated from it; 9.96 lb/sq.in. resulting from a possible sodium fire, and 3.485 lb/sq.in. from another possible accident of an unspecified kind.

(ii) Maximum internal under-pressure of 1.68 lb/sq.in. gauge made up as follows:—

0.675 lb/sq.in. resulting from a possible rise in the atmospheric pressure while the reservoir is isolated from it; 0.3 lb/sq.in. resulting from oxygen consumption in a possible sodium fire, and 0.697 lb/sq.in. resulting from the sudden emptying of water from the internal tank into the pressure vessel.

It should be stressed that the coincidence of the different terms, each very exceptional, involving the ultimate limits of over- and under-pressure envisaged, must be considered as something that is highly improbable.

Allowance was also made in the calculations for wind forces with a dynamic pressure of 39 lb/sq.ft which may be considered the maximum likely in our regions, and a snow load of 8.2 lb/sq.ft.

The stresses due to the polar travelling crane were not taken into consideration, as this bears entirely on the internal concrete wall.

BR III Resistance

With regard to the BR III, resistance was calculated on the basis of a maximum internal over-pressure of 45 lb/sq.in. gauge. In view of the moderate size of this pressure vessel and the thickness of the relatively strong walls which result from the allowance made in the calculations for a major incidence of over-pressure, resistance to under-pressure is very high here and this condition can be ignored.

Allowance was also made in this building for secondary stresses attributable to wind and snow.

The calculation of a cylindrical body under internal pressure is carried out on a basis of well-known elementary formulae which allow the minimum standard thickness to be determined.

Thus, by applying the NBN Standard, a thickness of 0.54 in. was worked out for the BR II at a pressure of 10.7 lb/sq.in. considered in the conditions, as the normal pressure to take for in the calculations, and by applying the Boiler Code, a thickness of 1.08 in. was selected for the BR III at a pressure of 44.8 lb/sq.in.

Theory Less Complex

It must be stressed however, that the reality is more complex than is indicated by the formulae, which, strictly speaking, are only valid for an infinite cylinder. At the ends, at the junctions with the base or dome, or where the base is embedded in the concrete foundations, secondary bending stresses occur, called stresses of discontinuity. These may be calculated, for example, by use of the formulae contained in technical Note B-111 of the CECM (Committee for Steelwork Design) entitled " Stresses in Tanks under Pressure " and drawn up by Mr. C. Massonnet, Professor at the University of Liége.

Now the specifications for the BR II pressure vessel required that the total stresses under the maximum pressure of 14.2 lb/sq.in. approximately should nowhere exceed $^{6}/_{10}$ of the elastic limit, which in our case is 9.9 ton/sq.in. This gave rise to the need for reinforcing the end rings, in relation to the thickness given above.

Again, consideration must be given, especially in the case of the BR II, to the resistance of the cylinder to internal depression, and to the dynamic effects of the wind, which according to the ABS standard, may be aligned with a loading for which the intensity of the pressure applied to the two symmetrical sectors is three times the dynamic pressure, which in our case is 116.75 lb/sq.ft. The simple formulae, valid for an infinite cylinder, show a very mediocre resistance to those two types of stresses for very thin (very high D/th ratio) vessels of the type of the BR II; more refined methods of calculation, which we have borrowed from Timoshenko or devised ourselves, allow account to be taken of limited strength and the effects of the ends. Permissible stresses are thus arrived at much higher than the previous ones. It must in addition be noted that when the structure is completed, the steel cylinder, as mentioned above, will be able to bear on the internal concrete wall via a layer of deformable material. Overall resistance to buckling and to wind force will then be very great, but it is important to have sufficient resistance to the effects of wind during erection.

Difficult Calculations

To these considerations must be added the existence of discontinuity stresses alluded to above, and local effects, difficult to calculate, which result from the cantilevering of some of the access arrangements. Finally, it is important to avoid an exaggerated deformation that might give rise to difficulties in erection. It is for all these reasons that we have adopted the thicknesses already given: 0.7 in. for the cylinder of the BR II, except for the bottom rings, which are 0.866 in. and the top ring, which is 1 in. It is then calculated that the average circumferential stress reaches the very modest figure of

5.5 ton/sq.in. under the maximum pressure of 14.2 lb/sq.in. that the combined maximum stresses in the zones of discontinuity do not exceed the ultimate value of 9.9 ton/sq.in. allowed in the specifications; and that wind resistance is sufficient, which experience has confirmed.

In the BR III, the thickness adopted is uniformly that of 1.12 in. the corresponding nominal stress is 5.8 ton/sq.in. at 44.8 lb/sq.in. and the combined maximum stress at the discontinuities is 8.95 ton/sq.in.

Calculating the hemispherical dome of the BR III did not occasion any particular difficulty; it was simply necessary to check whether the stresses of discontinuity were moderated there.

Internal Depression

The calculation of the torispherical dome of the BR II and the torispherical base of the BR III, under the effect of internal over-pressures, was carried out following the formula of the ASME Boiler Code; it was subsequently checked by evaluating membrane and discontinuity stresses by the methods of Professors Timoshenko and Massonnet.

It was the problem of the resistance to internal depression of the BR II dome that occupied our attention longest. This dome, in effect, must support by itself (as it is not helped by a concrete wall) the maximum depression of 1.7 lb/sq.in. envisaged by the specification, to which must be added the effects of self-weight and snow, which have obviously the same effects as those of a depression.

Of course measures have been taken to avoid the maximum depression envisaged from being set up in the pressure vessel (use of anti-vacuum valves); the question, however, had to be gone into closely, as the proportions of this dome depart widely from those dealt with by the usual formulae of the codes. We have used the ordinary semi-empirical formulae of Professor Klöppel, and a comparable formula of Tsien's; we have also been in touch with the technical directorate of ASME.

All these considerations allowed us to conclude that safety was adequately ensured and the thickness of 1 in. (26 mm), required by the Boiler Code, was finally adopted. This value is more than adequate from the point of view of resistance to internal pressure.

Generally speaking, the reinforcements to the various types of inlets were calculated in accordance with the Boiler Code of the ASME.

For the more important inlets, viz., the vehicle airlock, and the two oblique sheaths of the BR II, and fuel transfer tank of the BR III, we considered this empirical method inadequate and have had recourse to more detailed mathematical research, involving use of the theory of elasticity.

The vehicle airlock of the BR II, being of great size and involving particularly complex shapes, necessitated long and difficult calculations, the details of which we cannot go into here.

A certain number of questions could not be completely and finally solved by purely theoretical research; it was necessary to have recourse to measurements and tests on a scale model.

Silicon Rubber Chosen

A prime example is that of the airtight joints of the airlocks and other inlets in the BR II. The specification lays down the possibility of the temperature in the pressure vessel reaching about 572°F., should an accident occur. It is clearly advisable even with such a temperature that the joints which ensure the airtightness of the airlock doors and the covers of the various sheaths should retain their properties. After searching examinations and experimental tests, we concluded that the material which had the best characteristics in this respect, good resistance at high temperatures and flexibility under crushing, is silicon rubber, a very interesting material only recently perfected.

After discussion, the shape adopted was that shown in Fig. 7.

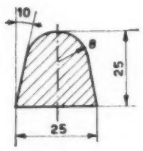


Fig. 7—Section through joint

Other questions relating to the vehicle airlock and to the oblique sheaths of the BR II were the occasion of a model being built, to a scale of 1:20, of the cylindrical body and the various inlets. For ease of fabrication, the base and cover were built flat and stiffened by stout girders.

An exhaustive tensometrical study was first of all undertaken of the vehicle airlock reinforcement by scores of resistance extensometers or strain gauges.

Greatest Stress

It was thus established, *inter alia*, that the greatest tangential stress in the reinforcement, along the inlet, in the round corners, was of the order of 8.25 ton/sq.in. a value reasonably close to that anticipated by calculation, viz., 7 ton/sq.in. at the same pressure of 14.2 lb/sq.in. Radial stresses in the same region came to still lower figures; along the straight parts of the inner edges of the reinforcement, the stresses were compressive, also of low value.

Along the external edges of the reinforcement, where it joins the wall, stresses were measured which, while still permissible, were higher than it had been possible to foresee. Thus, on the horizontal axis of the exterior wall, they reached some 12.7 ton/sq.in. (20 kg/sq.mm) in a radial direction.

Local Bending

When the cause of these abnormal findings was sought, it was observed that on the inside, stresses at the corresponding points were in compression and of the order of 6.35 to 10.16 ton/sq.in. (10 to 16 kg/sq.mm). It was thus essentially a phenomenon of local bending. It could not have arisen either from a variation in the rigidity of the wall due to its variation in thickness, as this would only account for a bending load of the order of 0.025 ton/sq.in. (0.04 kg/sq.mm), or form the action of pressure on the base from the tubular inlet representing the airlock, because it had been observed experimentally that if this effect were equilibrated by an external force, the above-mentioned stress values were not lowered at all. It seems, finally, that the bending loads cited above are due to the fact that, in consequence of welding deformations, the reinforcement was not in the continuation of the wall; summary calculations, based on this assertion and on certain reasonable hypotheses,

thus indicate fairly high bending loads.

The scale model allowed other interesting results to be obtained.

For example, the resistance to buckling of the cylindrical body of the vehicle air lock under the maximum depression envisaged had been largely checked by the traditional formulae. It might, however, be suspected that the presence of a heavily laden vehicle might provoke some premature instability by the deformations it would impose on the cylinder. We were able to satisfy ourselves experimentally that this fear was a vain one and that safety was well assured again here.

Use of Model

Finally, the scale model, with its inlets simulating the most critical of the inlets on the actual structure—the vehicle airlock and the oblique sheath—was subjected to an internal air pressure of 28.4 lb/sq.in. (2 kg/cm²) double the calculated pressure.

The special character of the BR II reactor has made necessary the provision of an airlock, of very large size, to permit the passage of heavy vehicles fetching or removing from the interior of the pressure vessel nuclear units or experimental jigs which may often be large and heavy. The main features required by the client are as follows: A useful passage section of 11 ft × 12 ft, a useful distance between doors of 39 ft 8 in. and a maximum vehicle load of 25 metric tons. Other conditions were determined by the size of the airlock in relation to the building it was to be fitted in. The limited length at our disposal, together with other considerations, led us to adopt sliding doors; the limited height suggest that the doors should slide horizontally, and not vertically as initially planned.

Impressive Airlock

The complete airlock is an impressive feature some 54 ft 9 in. long, 34 ft 1 in. wide and 24 ft 11 in. high.

The two doors, which cannot be opened simultaneously, are fitted in such a way that the internal overpressures of the vessel are brought to bear on their jambs. Each is made up of a plain steel sheet 2.56 in. This design proved more economical and more interesting than those in a ribbed or box-section structure, which, though undoubtedly lighter are much more difficult to construct.

Airtightness between door and jamb is obtained via two interlocking joints in silicon rubber, of the type described above.

Each of the doors is compressed on its joints by 12 screw-jacks, which press the joint down approximately 0.102 in. by exerting a total force of about 13 metric tons. This force is sufficient to prevent the doors coming apart in the case of maximum depression in the vessel. On the other hand, in the case of maximum high pressure, the pressure on the joints goes up to 137 metric tons, and their deflection is then about 0.2 in.

With regard to the screw-jacks, it may be noted that the screw is of the double entry type, irreversible, and mounted on Timken bearings. It turns in a nut forming a jack head whose rotation is prevented by a block and hence transmits its motion. The head is fitted with Schnor bearings, which give it a certain elasticity. Furthermore, to permit easy adjustment and thus to obtain the simultaneous bearing on the door of the different screw-jacks distributed along its perimeter, the part which the above-mentioned nut slides in is itself rotatable and can be firmly blocked in any position.

Care over Screwjacks

The blocking and unblocking movement of the screwjacks is governed by an electric motor through the intermediary of reduction gears and a Renold endless chain, which simultaneously encompasses the differentials mounted on each screw-jack, one of which is motive, and three surge pulleys, judiciously placed, and ten fixed deflector pulleys.

Much care has been devoted to ensuring accessibility to the screw-jacks and their control, ease of assembly and adjustment, and the lubrication and maintenance of these units.

Parallel with the automatic control, each door is equipped with a manual control of the screw-jacks by a hand wheel with a high reduction, which can be operated from either side.

The simultaneous opening of the two doors of the airlock is prevented by both electrical and mechanical means.

Fig. 8—Fuel transfer tank of the BR III

Each door is suspended from two traverse carriages one electrically and the other manually controlled from either side. These carriages rest on their rail via four rollers mounted on bearings; four other, smaller rollers ensure free running without risk of jamming. These carriages have a second movement, perpendicular to the first, allowing the door to be displaced when acted on by its screw-jacks. The effective free running of the door on its track when moved and its safe stopping against shock absorbers are ensured by various mechanisms consisting for the most part of standard units of Cockerill-Ougrée equipment.

Automatic Control

The various operations involved in opening and closing the doors by electrical control are carried out in succession entirely automatically, directed from a single button, through the action of limit switches and relays.

A word in conclusion may be said about the fixed structure of the airlock. It consists of an inlet opening with a reinforcement inserted in the pressure vessel wall, an intermediate cylindrical body with a diameter of 14 ft 9 in. and a length of nearly 27 ft 10 in. and two door casings which receive the greater part of the mechanism. The door jambs are

(*Continued on page 473*)

HEAVY WATER

French Research and Processing

by F. R. Paulsen, BSc, PhD, FRIC, MINucE

FRENCH interest in heavy water, like that of the other nations with advanced nuclear technologies, may be divided into two broad headings. Firstly, the use of heavy water as a moderator in fission reactors is of importance for present and immediate future power prospects. Secondly, the use of deuterium in fusion reactors may hold an important clue to future power production. This possibility, though, is rather more remote.

Reactions in which deuterium can take part, with the liberation of thermonuclear power, are the following:

(*a*) ${}_1{}^2D + {}_1{}^3T = {}_2{}^4He + {}_0{}^1n + 17.6$ Mev
(*b*) ${}_1{}^2D + {}_1{}^2D = {}_2{}^3He + {}_0{}^1n + 3.25$ Mev
(*c*) ${}_1{}^2D + {}_1{}^2D = {}_1{}^3T + {}_1{}^1p + 4$ Mev

The high figures for the liberated energy in these reactions are sufficiently attractive to justify the expenditure of much time and effort on the solution of the many problems which accompany this search for a source of cheap power. F. W. Aston, wrote in his classic "Mass Spectra and Isotopes" in 1933: "Notwithstanding the immense amount of research work done on the discharge at low pressures many of its phenomena are not yet fully explained." And what was true nearly 30 years ago is still applicable. Our knowledge of discharge phenomena has increased immensely, but so also has our awareness of further complicating features. Until all these problems and difficulties are solved, nuclear power from fission processes is still only a dream, albeit a dream which eggs man on to intense research.

High Quality Work

Although Saclay's machine for the investigation of thermonuclear power is by no means as impressive as the British thermonuclear apparatus, there can be no doubt that the French work is of high quality, and there is as reasonable a chance of a break-through in France as in most of the countries at present engaged in this type of work. P. Hubert, head of the controlled fusion work at the French CEA, points out, in his article "La Fusion Contrôlée": "Une crainte sérieuse commence à se manifester; qu'il en resulte une condamnation du principe même de confinement magnetique." He further says: "Aucune des principales voies d'approche n'a encore été abandonnée comme impracticable, mais aucune voie, non plus, ne paraît suffisament prometteuse pour bénéficier d'une concentration des efforts au détriment des autres." It is for this reason that French work on thermonuclear fusion is concentrated on "collective phenomena" and more especially, on work of a collaborative nature within the sphere of agreements with Euratom.

Very Good Moderator

Of greater urgency at present, however, is the solution of the many technical problems involved in the use of heavy water in fission reactors. Heavy water is perhaps the ideal moderator, since its low tendency for neutron capture and its ease of handling are very attractive properties. Against these advantages must be set the very high cost, and the difficulties raised by its radiolytic decomposition. Its excellent moderating powers make possible reactor cores of very high flux and small size, factors which are, of course, very attractive when designing propulsion units or research reactors especially. But power stations would also present advantageous features if they could be based on heavy water instead of graphite as moderator. Heavy water, however, presents many difficulties in this use. It should be possible to obtain power outputs of the order of 2 MW/tonne of heavy water. The present state of knowledge of the many technological factors involved makes an economic comparison of the various types of power reactors well-nigh impossible.

The problems which arise when heavy water is used in reactors fall into four groups: those due to induced radioactivity of elements present in the material; those arising from radiolysis of the heavy water; corrosion difficulties; and problems of pollution.

0.2 Per Cent of H_2O

Radioactivation may result from reactions of fast neutrons, slow neutrons, and gamma rays. These reactions may be summarized as shown in Table I.

The heavy water employed for reactors may be taken as 99.8 per cent. pure, so that the light water content is about 0.2 per cent. The concentration of D, H, and O16 are thus approximately 66.6, 0.13 and 33.3 per cent. atomic respectively. The isotopic composition of the oxygen will be very close to that of natural water, namely 99.76, 0.04 and 0.2 per cent. by weight of the isotopes 16, 17 and 18 respectively. Assuming a neutron production of 10^{13}/sq.cm/sec in the reactor, the production of tritium by radioactivation of the deuterium will result in an activity of 5×10^{-3} curie/c.c., assuming the heavy water to be circulated for a year.

Table I—Summary of Possible Reactions of Induced Radioactivity with Heavy Water

Type of reaction	*Atom involved*	*Cross-section, σsq.cm*	*Atom formed*	*Decay period*	*Radiation*	*Energy of radiation*
$n{:}\gamma$	${}_1{}^2D$	0.4×10^{-27}	${}_1{}^3T$	12 years	β	6 Kev
$\gamma{:}n$	${}_1{}^2D$	1.6×10^{-27}	${}_1{}^1H$	Stable	—	—
$n{:}\gamma$	${}_1{}^1H$	0.3×10^{-24}	${}_1{}^2D$	Stable	—	—
$n{:}p$	${}_8{}^{16}O$	0.2×10^{-28}	${}_7{}^{16}N$	1.3 sec	γ	6.5 Mev
$n{:}\gamma$	${}_8{}^{17}O$	0.5×10^{-24}	${}_6{}^{14}C$	5,200 years	β	0.155 Mev
$n{:}\gamma$	${}_8{}^{18}O$	0.2×10^{-27}	${}_8{}^{19}O$	29.5 sec	β, γ	1.6 Mev

The radiation emitted by the tritium is very soft, and presents little hazard externally. However, the "old" irradiated heavy water does necessitate certain precautions in handling, and special respirators need to be worn. In the case of the radioactivity resulting from the isotopes of oxygen, that from N16 and O19 is so short-lived that the inclusion of a delay tank in the circulating system removes all hazards. Activity due to the C14 is also negligible, because of the low concentration of the isotope of oxygen giving rise to this species. The induced radioactivity of heavy water, although small, is sufficient to enable monitoring devices to be used for the detection of leaks of the precious substance.

Energy Breakdown

The radiolysis of heavy water depends on the large energy liberation during the fission of uranium. Breakdown of a single uranium atom causes the release of 204 MeV, which may be attributed to the following causes:

Kinetic energy of fission products	167 Mev
Prompt gamma rays	6 ,,
Kinetic energy of fission neutrons	5 ,,
Fission product decay, gamma rays	6 ,,
Fission product decay, beta particles	8 ,,
Neutrinos	12 ,,
	204 ,,

This energy, liberated within the heavy water used as moderator, causes the splitting of the molecules, according to the equations: $H_2O = H + HO$, $D_2O = D + DO$, $DOH = H + DO$, $DOH = D + HO$. The number of ion pairs formed per micron of trajectory is 12 in the case of gamma photons, but as high as 4,800 with alpha-particles from the fissile materials. These decompositions are followed by recombinations such as $H + H = H_2$, $H + HO = H_2O$, $2HO = H_2O_2$, $HO + H_2O_2 = O_2H + H_2O$, $HO_2 + HO = H_2O + O_2$, $H_2O_2 + H = H_2O + HO$ and $H_2 + HO = H_2O + H$, together with the reactions in the corresponding deuterium systems.

From the point of view of radiolysis resulting in the formation of gaseous products which escape from the system, reactions favouring such an evolution may be termed "progressive," while those in the opposite sense are "retarding" or "retrograde." The chief progressive reactions are $2H_2O = H_2O_2 + H_2$ and $HO_2 + OH = H_2O + O_2$, while reactions such as $H_2O = H + HO$ will be retrograde. We may denote by G_h the yield of the progressive reaction $2H_2O = H_2O_2 + H_2$, expressed as the number of molecules of hydrogen liberated per 100 eV of energy absorbed. Similar definitions can be applied to the yield of retrograde reactions, which we may designate as G_r. Typical values for these yields are:

Radiation	G_h	G_r
Gamma rays	0.42–0.46	2.12–2.74
Reactor, with heavy water	0.38	2.7
Reactor, with graphite	1.18	1.57
Alpha particles from B10 (n:α)	1.25	—
Fission of U235	1.1–1.8	0

When the yield of hydrogen, in c.c/kWh of energy liberated, is plotted against the resistivity of the water, in ohms/sq.cm, it is found that the former changes little as resistivity increases, but that at a certain value of the resistivity, the hydrogen yield suddenly increases rapidly, tailing off again at higher resistivity values. The yield of hydrogen is, then, a function of the purity of the water.

Decomposition of the water by radiolysis is reduced by increasing purity. But when the impurities are such that the resistivity is about 15,000 ohms/sq.cm, there is the sudden increase in hydrogen liberation, increased impurities then having little further effect. Halogen ions, such as chloride and bromide, have a very marked effect on radiolysis, so that complete removal of such ions by means of deionization resins is obviously desirable.

Radiolysis Irksome

In the case of a reactor using graphite as moderator, most of the kinetic energy of the fission fragments, which after all represents about 80 per cent. of the total energy liberated during fissions, is dissipated in the graphite, so that little is available for radiolysis. Only the neutron and gamma energies, in fact, will result in radiolysis. For this reason it is very obvious that radiolytic gas evolution must be a more irksome problem in homogeneous reactors than in heterogeneous ones.

In the case of the French EL-1 and EL-2 reactors, the deuterium liberation amounts only to 120-140 c.c./kWh even under the worst conditions. The gas pressure builds up with time, but not linearly, since it tails off, tending to become constant after a certain time. This is because reactions which result in gas release are reversible. By the laws of reversible reactions, it is reasonable to suppose that addition of hydrogen to the closed system would suppress radiolysis. This, in fact, is the case, and at pressures of hydrogen equal to 2 kg/sq.cm, the radiolysis becomes virtually zero. The same remarks apply equally to the suppression of radiolysis in heavy water.

Continual Recharging

In the case of boiling-water reactors, it is impracticable to suppress radiolysis in this way. Keeping an atmosphere of some inert gas, such as helium, above the liquid will help. Nevertheless, the decomposition gases will accumulate. In the case of heavy water, there is present not only the explosion hazard, but the important factor of the loss of an expensive material. For this reason the gases are normally passed continuously through a catalyst chamber, so that they recombine to form heavy water again, this being returned to the reactor system.

Another feature which becomes of considerable importance in reactors for power generation is that radiolysis is a highly energic process. In a water-moderated, homogeneous reactor, for example, the production of gases will amount to 10 litres of hydrogen and 5 litres of oxygen per kWh, and this process absorbs about 4 per cent. of the total energy production. It has been found that the cupric ion (Cu2+) is able to activate hydrogen and so assist in the recombination of radiolytic gases, so that gas evolution can be reduced by as much as 90 per cent. This is a valuable discovery which has greatly assisted the development of homogeneous reactor systems.

In suspension type reactors, the conditions are intermediate between those in homogeneous—and those in heterogeneous—reactors. It is found, however, that radiolysis decreases as

the size of the suspended particles increases. However, there are problems of mechanical engineering which makes it impossible to increase the particle size above a certain value, as difficulties of circulation become very seriously increased.

Pollution of heavy water may give rise to three separate serious difficulties. Firstly, the decreased purity results in increased radiolytic gas formation, as mentioned above. Next, there will be higher induced radioactivity due to elements introduced. Thirdly, some of the impurities introduced, *e.g.*, boron, may have a high cross-section for neutron capture, and so these impurities will certainly prejudice neutron economy.

In the liquid and vapour phases, there is a rapid exchange between isotopes. Any water in the heavy water will decompose preferentially and the hydrogen in the radiolysis gases then exchanges with the heavy water, giving rise to HOD and deuterium gas. Unless an efficient recombiner can be used, the deuterium gas being not readily liquefied, this valuable element may be easily lost to the system. It is highly essential, then, to maintain the high initial purity of the heavy water, preventing the entry of all traces of moisture and other impurities.

Similar Corrosion Problems

The use of heavy water as moderator in reactors introduces, as might be expected, a number of corrosion problems, due to the change from a stationary solid moderator such as graphite to a moving liquid. Fortunately, since the corrosion problems met with in the use of heavy water are virtually identical with those encountered with ordinary water, no really new considerations arise.

While the use of heavy water has produced its problems, there are many others in the production of this costly material. The manufacture of heavy water has, of course, been the concern of French scientists and engineers for several years now. The method of electrolysis produces in Norway several tens of tons annually, but has not been seriously considered in France. The fractional distillation method has likewise been passed over as impracticable. Distillation of liquid hydrogen supplies about six tons of deuterium annually in Germany, and is also used in the U.S.S.R. In France, it has been investigated. Isotope exchange reactions have been accepted as the most feasible. The choice of reaction, however, is still a matter of debate.

In natural water, for each million atoms of ordinary hydrogen (H) there are about 150 of deuterium (D), present as D_2O and DOH. There is an equilibrium between the various species: $H_2O + D_2O = 2HDO$ so that the equilibrium constant K for the reaction is dependent on temperature, reaching 1.5 at 3°, 100 at 100° and 101.5 at 103°C. A typical isotope exchange reaction will also be reversible. Thus, for example, H_2O(liquid) + HDS(gas) = HDO(liquid) + H_2S(gas). For this reaction the equilibrium constant is given by $\left(\frac{HDO}{H_2O}\right)\left(\frac{H_2S}{HDS}\right) = 2.34$ at 25°C. If hydrogen sulphide (H_2S) gas is passed up through a scrubbing tower down which water passes, and an equilibrium state is assumed, the concentration of deuterium in the gas will be increased by exchange reaction. Now suppose this gas, issuing from the top of the scrubbing tower at 25°C., passes to the base of a similar scrubber tower in which water descends at 100°C., since the K value at 100°C. is 1.92, the deuterium will tend to pass back into the liquid phase again by isotope exchange. This method is one which is very favourable, since it enables deuterium in ordinary water to be concentrated up to the point where fractional distillation can be applied. The drawback is that the K values, and their variation with temperature, limit the yield, and 300,000 tons of water have to be processed to yield one ton of heavy water. The more favourable isotope exchange reaction in which ammonia is used in place of hydrogen sulphide is more satisfactory from the thermodynamic point of view, and one which will be of great future importance.

Broadly speaking, it will be seen that the nuclear applications of heavy water have presented the reactor technologist with a fairly formidable programme of investigational work, but none of the problems are likely to prove insuperable.

BR II & BR III

(*Continued from page 470*)

separate pieces in the shape of a frame, carefully manufactured independently, which are bolted to the main structure, adjusted with shims and the joints covered by a light welded plate to ensure airtightness. This is done to obtain a perfectly vertical and undeformed bearing face. The screw-jacks are housed in other frames, of box section and very rigid, surrounding the airlock passage opposite the doors.

The personnel airlocks of the BR II and BR III are constructed in a very similar manner. The useful passage section of the doors is 6 ft 3 in. × 3 ft 6 in. and the distance between doors 12 ft 6 in. Closing is effected by 12 wedge bolts, uniformly distributed along the periphery and activated by two eccentric cams driven by a single reduction mechanism and a handwheel. A very simple mechanical locking device prevents the two doors opening simultaneously. In addition, when the bolts start being withdrawn, an aperature is uncovered to ensure equilibrium of pressure on both sides of the doors, which thus obviates difficulty in parting the doors or too sudden an opening, as the case may be (Fig. 8).

The transfer tank of the BR II is designed for the passage, under water, of reactor fuel units, from the interior to the exterior of the pressure vessel. It is made up in section of two semi-circles with a radius of 2 ft 11 in. separated by a straight part 7 ft 6 in. deep; its length is about 20 ft 6 in.

For steel walls in contact with water that may become activated in conditions of service, it is currently the rule in nuclear building to employ stainless steel. In this way, the products of corrosion, made highly radioactive, and drawn along by the movement of the liquid, can be prevented from polluting the whole circuit and making decontamination more difficult.

The fuel transfer tank referred to above has not escaped this rule, and has been carried out in plated steel, that is, ordinary carbon steel, clad by rolling, with a 0.12 in. thick layer of stainless steel. These sheets of plated steel were supplied by the Swedish firm of Uddeholm.

(*To be continued*)

This article is published through the courtesy of Acier-Stahl-Steel. The photographs are by Cockerill-Ougrée.

Business built on versatility

reliability and promptness also vital

A HARWELL engineer wanted a complicated piece of gear actuating mechanism made to his own specification. The workshops were busy and he wanted it in a hurry. Somebody suggested " Graviner will do it." He took up the suggestion and was pleased he did. The equipment was delivered exactly as ordered and well within the time promised.

Later, another engineer, requiring some small plastic made cable guides, also went to Graviner. He too, was more than satisfied with the results obtained.

Whereas most firms rely on specializing in one particular line, the atomic energy division of the Graviner Manufacturing Co., Ltd., has built up its reputation and business on versatility. " We'll try our hand at anything," says works manager Mr. Van de Broek. " If anybody such as the Atomic Energy Authority want a special job done and we think we can cope, we'll do it." Hence the wide range of products that are turned out of Graviner's factory at Gosport, Hants—lead shielding, graphite reactor reflectors, electronic equipment for rocket machinery, massive irradiated fuel " coffins," nimonic components, and paraffin wax compositions, to name just a few.

ZED-2 Contract

The company recently undertook the design, fabrication and installation of the 70-ton graphite reflector of the ZED 2 reactor at Chalk River, Canada. They have a running contract with the Atomic Energy Authority for the supply of lead shielding. A graphitising furnace has been made for the General Electric Co., Ltd., and another is under construction for Hawker Siddeley. A magnet for neutron beam focusing on the NIMROD 7 GeV proton synchrotron at Harwell was fabricated by Graviner, who have also supplied a complete shielding unit for the Danish Atomic Energy Commission. These are just a few of the contracts held by Graviner and orders continue to flow in, both from home and overseas.

During the last 12 months the factory at Gosport, Hants., has had to be considerably extended to 48,000 sq.ft. and the staff increased to about 300 to cope with the work undertaken. There is room on site for even further expansion.

Completed on Time

Graviner's success has not, of course, been due to versatility alone. Reliability and promptness have played their part too. It is said that on one recent large Authority contract Graviner were the only contractors to complete their order on time. Hard-pressed scientists and engineers remember this sort of thing when work is required in a hurry—hence their lack of hesitation in recommending the company for small special jobs such as the making of actuator mechanism or a set of wave guides.

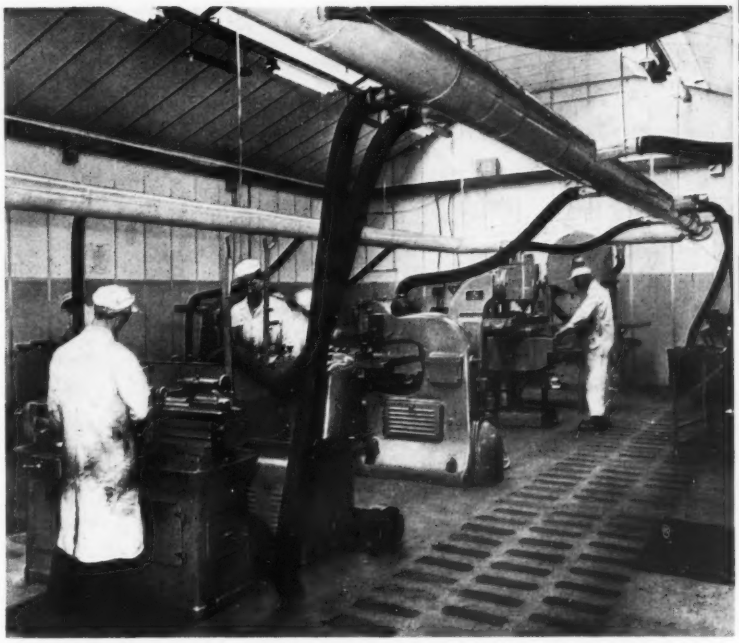
To ensure reliability only fully qualified technicians and highly skilled craftsmen are employed on work demanding skill and accuracy. The best tools are used and special manufacturing facilities, such as the graphite workshops, are maintained at the stringent standards required by the company's customers.

Accident Started It

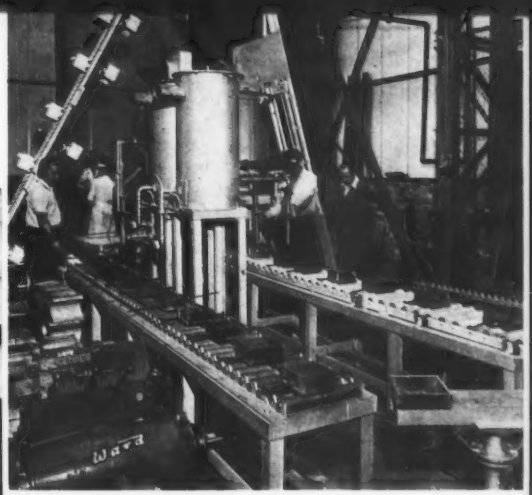
Graviner had of course a reputation long before entering the nuclear field. The firm was established in 1933. A retired captain of the Indian Navy, shocked by the death of a close friend in a car accident, introduced a device designed to prevent fires in overturned vehicles. Later, it was adapted for use in aircraft and won a competition organized by the Air Ministry. In fact, it was the only equipment submitted that complied with the minimum requirements of the Ministry.

Following this success, orders for the equipment followed. Captain Salmond and his business associate, Mr. A. Mathison, the present chairman and managing director, were well and truly in business. Thus started the Graviner Manufacturing Co., Ltd. Even to-day the Graviner aircraft fire protection equipment is the only apparatus of its kind approved by the Civil Air Registration Board and it is the company's proud boast that all the aircraft

One of the workshops at the Gosport factory



View of the graphite machining room. Floors are fitted with non-slip pads



The lead melting plant for the fabrication of shielding bricks

exhibited at this year's Farnborough Air Show were installed with their equipment.

From aircraft safety, Graviner turned their attention to the design and manufacture of oil mist detecting equipment for marine diesel engines. They then went in for explosion detection apparatus for use in factories and plants, such as flour mills, where heavy dust explosion hazards exist.

Shortly after the war the firm were asked if they could make some apparatus of special design that was required for research into nuclear energy. Graviners were only too pleased to comply; thus started their rewarding association with Harwell and other nuclear research establishments.

Compact Lead on Way

Currently Graviner use the well-established melt-mould method of fabricating lead bricks, machining of interlocking parts taking place after the moulding. It is understood, however, that they soon hope to replace this with a new, more efficient compression method. Appropriate apparatus has been designed and a patent applied for it and it is now waiting to be built and installed.

Like any other integrated well-organized firm Graviner has its own research and development staff of fully qualified scientists, technicians and draughtsmen. Not only do they carry out work which is utilized solely within the firm such as this lead apparatus but also will undertake studies and investigations for customers.

24-Hour Working

To meet the demand for lead bricks, which are required by many organizations other than the Authority, the lead melting plant is kept in round-the-clock operation. Lead is of course used for other purposes than brick-making—it forms an essential part of radioactive material containers. Graviner have made a wide range of these, the largest being a 20-ton irradiated fuel coffin supplied to Windscale.

To enable checks to be made on the effectiveness of the lead shielding, the firm has a special testing department equipped with its own radioactive sources and X-ray equipment, as well as with the usual physical measuring apparatus. All products are in fact, thoroughly tested before being delivered. No chances are taken in sending customers faulty materials or equipment.

One material which needs very careful handling and for which Graviner have had to provide special facilities is graphite. For reactor use it has to be of the highest quality and in Britain it can be bought only from the U.K. Atomic Energy Authority. Precautions have to be taken to prevent contamination—the workshops and stores are air conditioned, drills, lathes, mills, etc. are fitted with dust extraction equipment and they cannot be freely lubricated, and the operators wear special protective clothing. A change room equipped with lockers and showers is provided for these men.

In addition to preventing contamination of the graphite the operators have to ensure absolute accuracy in their machining. The reflector for the Canadian ZED-2 for instance consists of 70 tons of graphite made up of 1,277 blocks. Each of these had to be machined to the finest of tolerances so that the whole reflector would not be out of line by more than 0.010 in.

To test their accuracy Graviner assembled the unit in the Gosport workshops before shipping it to Canada. Further precaution was taken by sending Graviner engineers to Chalk River to supervise its installation in the reactor.

In transit one of the graphite bricks was damaged and a replacement had to be flown out. This was the only mishap and the Canadian authorities were extremely satisfied, indeed impressed, by Graviner's handling of the project.

With several happily executed contracts such as these behind them, linked with the closely trusted association with the Atomic Energy Authority, the Graviner Manufacturing Co., Ltd., have an assured future. And through their reliability and integrity, Graviner's name will become as well-known in nuclear energy circles as those of many of the larger, more powerful organizations.

Engineers at the Lawrence Radiation Laboratory in America sought a material to replace the fused quartz used in the fabrication of the annular tank segments of their 340 MeV electron synchrotron. After testing many different substances they found the best material was laminated epoxy resin. How it is applied is described in this article

Epoxy Resin Laminate
Problem with Synchrotron Solved

by James O. Turner,
Lawrence Radiation Laboratory, University of California.

AN unusual laminating technique involving plastic foam was used to shape a fibreglass-reinforced epoxy resin segment of an annular vacuum tank for the Lawrence Radiation Laboratory's 340-MeV electron synchrotron. In more than a year of service so far the epoxy resin has demonstrated that the laminated segment is more economical to produce and is less subject to breakage than fused quartz, glass, or ceramic. Also, that it is a good dielectric material, has excellent vacuum properties, and low vapour pressure, and so far has shown no radiation deterioration. Finally, the laminate can be machined easily for the ports and windows required for various radiation experiments.

This application of plastics was developed in the search for a substitute for quartz, which does not lend itself to modification of segments for different experiments. The electron synchrotron accelerates electrons to 340m. electron volts in a doughnut-shaped vacuum chamber. The chamber is made up of eight removable segments, all of which were formerly made in quartz. Experimenters' requirements may call for windows or openings in one of these segments, which means that it ought to be possible to cut a tank segment without danger of breakage.

Quartz Expensive

Several different non-conductive materials were tested for segment use. Fused quartz, glass, and ceramics each had disadvantages. Quartz was the only material found usable until the epoxy resin laminate was developed, but quartz is expensive, subject to breakage, and difficult to cut.

Segments made of glass collapsed when vacuum was applied, probably because of residual strains. Ceramic segments proved unsuitable, because high shrinkage meant difficulty in holding required tolerances. Metals could not be considered, because eddy currents set up in any conducting material by the changing magnetic field of the synchrotron would distort the magnetic field and cause ruinous heating.

Obviously a completely different type of material was needed—one that could be worked easily, that could be machined, and that would offer high strength and dimensional stability along with good dielectric properties. It was felt that an epoxy construction should meet all these requirements. These resins had been used successfully in other casting and laminating applications.

Shaping a Problem

The remaining problem was how to shape the epoxy. A technique was eventually developed by which we made a highly satisfactory laminated epoxy resin segment. That segment, now in service, has replaced one of the original quartz segments in the doughnut chamber. More of the quartz segments may be replaced with similar laminates in the future.

The annular vacuum tanks, situated between two broad pole tips, has a radius of one metre. Each quartz segment of the tank is about 31 in. long and represents 45° of arc. In cross section it approximates an oval 6 in. wide and 3 in. to 4 in. high, but is of complicated geometrical shape.

At first an attempt was made to duplicate the shape of a quartz segment by pouring epoxy casting resin between matched male and female laminated moulds. But the shape of the segment made construction of a core too complicated. There seemed to be no way of removing the core from the segment after casting. The idea of an aluminium core made up of several mating pieces was considered, but eventually abandoned as too difficult and expensive.

A system involving a low-melting-point alloy (below the softening point of the epoxy) that could be melted out afterward was then considered. The core was cast of this alloy in a laminated epoxy mould that had been built up on a wood pattern. Although this method was better, the core proved too heavy and awkward to handle.

Next approach was to try a foam-in-place material for the core. A rigid polyurethane was foamed in an inner mould. This foam provided a substantial core with good surface characteristics. The core was then positioned inside the outer mould so that an epoxy resin casting could be made.

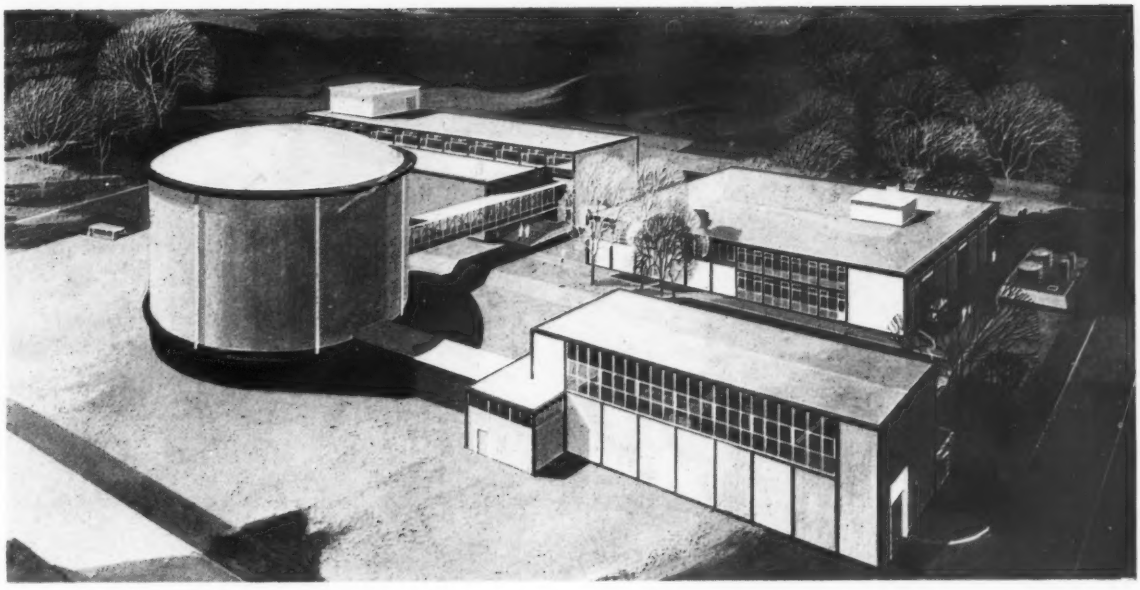
This technique was fine—up to the point of removing the core which was to be done by dissolving it. Here a snag was struck, as a result of polyurethane foam being quite resistant to solvents. After about two-thirds of the foam material had been removed with various high-powered solvents (acetone, methyl ethyl ketone, etc.), the remainder was soaked in a container full of solvent. But the foam, instead of dissolving, took up the solvent and expanded so much that over a weekend broke the epoxy casting.

Preparing Foam Core

The next step was to prepare a core from foam material that could be readily dissolved. Polystyrene foam, which is easily dissolved by any one of several solvents, was the obvious choice. It was obtained in block form, then sawed out to roughly the size and shape of the segment.

The foam was cut to exact core section by a thin stainless steel ribbon, that was ground down to a knife edge, formed into a loop of appropriate cross section and heated electrically. The block of foam was placed on a table that could be rotated, over which the cutting loop was fixed at the proper radius. As the table was turned and the foam

(*Continued on page 484*)



DRAGON—Civil Engineering Plans

BUILDING and civil engineering work on the OEEC DRAGON reactor project at the Winfrith Atomic Energy Establishment is being undertaken by the Turriff Construction Corporation Ltd. The contract, which is worth over £1m., covers the construction of the main reactor building, four other major buildings, and ancillary buildings, connecting links, service ducts, drainage, and the completion of the roadway layout.

A preliminary or " opening-up " contract has already been carried out by Turriffs for the foundations of the reactor buildings and the initial stages of the roads and services, including the approach road from the main area of the Winfrith AEE site.

For the foundation slab of the reactor building it was necessary to excavate a circular hole approximately 40 ft deep and 120 ft diameter at the bottom, through the peat, silt, sand and clay pockets which lie below the surface of this part of Winfrith Heath.

To keep the area of disturbed ground to the minimum, the sides of the excavation were dug to the steepest batter that would stand unsupported with safety in such ground (50°), giving a diameter at the top of the hole of nearly 200 ft.

The greatest physical difficulty of construction work on Winfrith site has been the presence of ground water in considerable quantities just below the surface, which necessitated the extensive use of wellpoint dewatering for all excavation except the very shallowest drains and foundations.

By siting the DRAGON reactor on a relatively high area of the heath it could be anticipated that ground water would not be met until a much greater depth had been reached. In the trial bore holes this was found to be at about 28 ft, and the method of excavation was planned accordingly.

Coping With Water

Well-points 18 ft deep were installed at 7 ft 6 in. centres below a berm formed at 27 ft before excavation was carried below this level, and two dewatering pumps, delivering a total of approximately 100,000 gal/hr lowered the water table ahead of the excavation, and kept the bottom dry for the time that it was exposed.

The saucer-shaped base of the excavated hole was blinded with a layer of weak concrete, into the centre of which was embedded, at a ceremony on April 27th, 1960, a stainless steel cylinder containing coins of the OEEC countries, and documents commemorating the occasion.

On top of this was poured the main foundation slab, 12 ft thick in the centre, in three layers, each containing several " mats " of heavy steel reinforcement, each resembling a huge 12-sided spider's web.

The slab is extended on the west side to form the base of the peripheral services duct, and on the north side as the foundation of the vehicle air lock, which will give access to the reactor building at ground level. Also incorporated in extensions of the foundation slab are two of the anchors for the guyropes of the 100-ton pole derrick crane which will be used to lift the reactor core itself and other heavy components into the building over the top of the 90 ft high walls of the containment structure.

Work Started in March

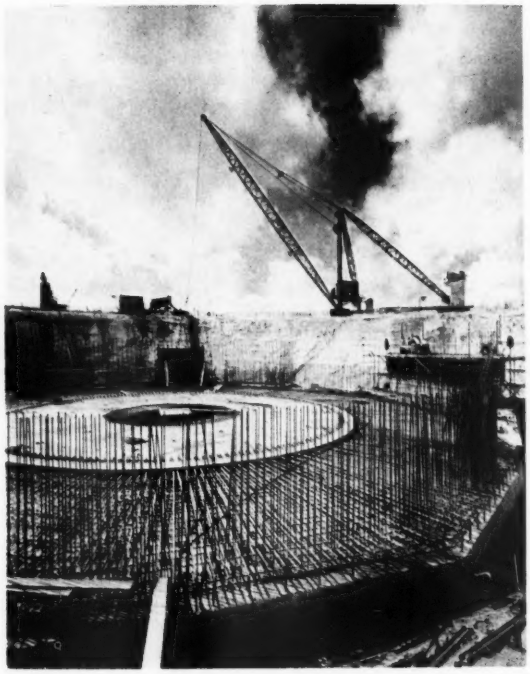
Excavation for the foundation slab was commenced on March 24th, 1960 and placing of the concrete was completed on July 18th, two weeks ahead of the contractor programme.

The most important item in the new contract is, of course, the main reactor building.

This is a cylindrical structure with a domed roof, 110 ft diameter and

110 ft 6 in. high above foundation slab. The exterior shell is formed of two concentric reinforced concrete walls 15 ft apart and generally 2 ft thick, and a domed roof of reinforced concrete 15 in. thick, containing an " umbrella frame " of heavy steel beams, and lined on the soffit with steel plate.

In the space between the two walls are the numerous chambers, situated on five floor levels, which contain the control points for operating the reactor and watching its functioning through radiation-proof observation panels, and various items of cooling and ventilating plant.



The reinforced concrete foundation for the DRAGON reactor

" Leaktight " Structure

A special feature of this concrete structure is that the containment consisting of the outer wall and roof is to be made " leaktight "—that is, sufficiently airtight to withstand a specified air pressure without leakage.

Normally this condition of reactor design is obtained by the use of a welded steel outer containment, such as the huge sphere which dominates the Dounreay establishment, but for DRAGON the structural concrete itself is to be made to fulfil this function. Although the technique of making concrete waterproof has been perfected long ago, very little is known of the factors which will ensure its airtightness, and practical experience is limited to work done during the last year or two in other establishments of the UKAEA. Nothing on the scale of the DRAGON containment has ever been attempted before, and this part of the concrete construction will in itself consistute a significant item of research.

Immediately inside the inner of the two cylindrical concrete walls is the inner containment of welded steel construction, the subject of a separate contract. Inside this again is further concrete construction, consisting of the support for the reactor core, which combines a biological shield of 5 ft 9 in. thickness of concrete of guaranteed density. This is continued above and over the reactor core and charging machine, with portions made removable for access or modification at any time. Between the core structure and the steel containment are a ring of cells formed in reinforced concrete, to house the fuel storage and handling equipment, primary and secondary heat exchangers and further inspection and experimental facilities.

Certain portions of the walls and partitions are in barytes concrete or iron shot concrete, where the extra protection afforded by these materials is necessary. All parts of the concrete structure incorporate innumerable openings and fixings that are required for access for personnel and materials and the passage of all the service pipes and cables, control gear, and observation panels; and one of the major problems of construction will be the effective sealing, against leakage of air or radiation, of all these potentially weak spots.

More Conventional

The other buildings on the DRAGON site, while comprising a major proportion of the contract value are, however, of more conventional construction and so easier to describe.

The largest of these is the services building, containing an electrical substation, with all necessary control gear, workshops, boiler house, and offices. The structure is partially steel-framed with concrete walls and roof.

The control building, partly two and partly three-storeys high, has besides the main control room, the administration offices, instrument rooms and workshops, various stores, and the change-room accommodation. Access to the reactor building is by elevated covered way at first floor level.

Connected to the reactor building by an enclosed vehicle access corridor, is the storage building, with annexes containing the offices for this department.

A separate building houses the main cooling plant for the reactor, and there are the usual layouts of drainage delay tanks and fuel tanks for the domestic heating boilers.

The main buildings and tank areas are connected by underground services ducts, large enough for adequate access to the many cables and pipes which they will contain, and there are three (in places four) separate systems of drainage covering all areas of the site.

As with all projects of this nature, planning is of the utmost importance. An overall programme for the building and civil engineering work has been set by the UKAEA to coordinate progress of construction with the delivery and installation of plant and equipment to be incorporated into the project.

'NUCLEARIST' writes . . .

COLUMNISTS have an advantage over their poor victims, thinks Mrs. Howorth, about whose book and Atomic Gardening Society I wrote in August. I am unrepentant about what I said. I know the talent on her Advisory Board, which, in the words of her letter to me, contains " retired or poliated BScs and many excellent experimental gardeners of the RHS." These people know what they are at, and it would be churlish to assume their efforts are misdirected. I am convinced that the idea of the Society is well-meant and sound. Mrs. Howorth, however, asks me to call " shame " on our professed geneticists for not producing a mutant, but I am not prepared to do this, for I consider the AEA knows its job. If she and her members can produce worthwhile results ahead of the workers in official laboratories I shall be one of the first to applaud.

Reading the account of the Society's first meeting at the Royal Society of Arts, I was struck by the programme. Dr. Gray's excellent lecture on the work of the experimenters, logical enough here, was followed by equally excellent, but surely out-of-place, talks by Dr. Dunworth on the DRAGON project, and medical research by Dr. Jean Pulsfor. Mrs. Howorth's personal regard (which I certainly share) for Frederick Soddy has led her into the error of making him a pioneer in bringing science into gardens. He would not have wished this. Again, Dr. Speas, of Oak Ridge, released irradiated seeds for lay experimenters and built up a profitable industry. But surely these two men cannot be called the real pioneers of mutant experiments. In spite of these criticisms, I should like to say that I sincerely wish Mrs. Howorth and the Atomic Gardening Society success.

* * *

At the IAEA-FAO Symposium on the effects of ionizing radiations on seeds, held in Karlsruhe during August, Dr. Arnold Sparrow, of Brookhaven National Laboratory, stated that " it seems that almost general agreement can be reached on the fundamental role of chromosome breakage in radiation genetics and in plant radiation biology." Work done so far may well save time for those starting work on new species, as it may be possible to predict the radiosensitivity of organisms not previously studied. A small group of experts should draw up specifications for seed irradiation experiments. Dr. Sparrow said that radiation is a serious business, " no longer appropriate or profitable for amateurs to play with." There is an important moral in this summing-up, of course.

* * *

I recently saw a new publication from Nuclear Translation Services, New York, an English-German bilingual glossary of nuclear energy terms. As in many other similar publications, there are many signs of lack of care in compilation. It is difficult to justify entries such as " adhesive," " acid," " aggravate " and " carbon tetrachloride." Again, " anaphase " is included, but not " metaphase " or " telophase"; " anode," but not "cathode"; " diatomic," but not " monotomic " or "polyatomic"; "efflorescence," but not " deliquescence " or " hygroscopicity"; " fuel discharge," but not " fuel loading." There are several errors, too. Thus, "epithyse" appears for "epiphyse"; "spaltbares material " is translated as "fertile material"; the entry "epithelium " is omitted from beneath the entry " epithelioma," thus causing confusion in the translations of the latter word; both " donut " and " doughnut " appear. The concept of the work is excellent, but the achievement could have been better. A more compact type and binding would be preferable.

* * *

New in the field of nuclear documentation is *Nuclear Engineering Abstracts*, published by Silver End Documentary Publications, Ltd., of London. With its three cumulative indexes of Publications Quoted, Authors, and Subjects, it provides ready reference to entries during the whole of a volume, and this is facilitated by ample cross-references. Much tolerance has been shown in the choice of subject matter, and some might be surprised to find in engineering abstracts references to papers on the use of isotopes in entomology, determination of carbon-14 in blood, strontium-90 in bone, and so on, to the exclusion of many articles of much less doubtful engineering context. However, the abstracting has been well done, and the entries are in most cases so full that there would seem to be little need to refer to original papers. I am convinced that this new publication will perform a valuable service to nuclear engineers, institutions and research organizations.

* * *

Scientists of Westinghouse Research Laboratories, Pittsburgh, claim to have found a new theory for the rusting of iron. They say that is due to hydrogen ions penetrating the iron and enlarging sites at which oxygen normally attacks the metal. Their conclusions are based on experiments at 835°F., at which temperature there is certainly a very small degree of ionization of water vapour. But this work is then extrapolated to room temperatures, at which the degree of ionization is very much smaller. If the action of the hydrogen ions is a mechanical one, then helium might be expected to have the same corrosion-accelerating effect; in fact, it is corrosion-inhibiting. It will be interesting to see if this new theory receives appreciable substantiation from other sources, and whether it is more workable than older ideas on the rusting of iron.

* * *

Canadian work on NRX and NRU has demonstrated clearly the advantages of reactors using natural uranium and heavy water. Fuel processing costs and waste disposal difficulties are much reduced, but annual fixed charges are higher than with other systems. Imports of heavy water from the U.S.A. need only cost about 10 per cent. of the amount of coal which would have to be also imported to produce a similar amount of energy. Economy is improved by achieving a burn-up of 10,000 MWD/tonne of fuel, the latter being Zircalloy-clad. This is to be compared with the 3,000 to 4,500 MWD for other natural uranium reactors. Burned fuel will be considered as waste, without plutonium recovery value, at least at first. Bi-directional fuelling is also used, so that an oil fuel element is always surrounded by new ones. There is very profound confidence in Canada in the possibilities of this type of reactor to produce competitive nuclear power.

PEOPLE

MR. H. R. SCHOFIELD, AssocIEE, has been appointed chief transmission project engineer to the Central Electricity Generating Board. Mr. Schofield was a pupil with the Stalybridge, Hyde, Mossley and Dukinfield Joint Tramways and Electricity Board from 1918 to 1921, and an assistant mains engineer until 1924. From 1924 to 1929 he was a contracts engineer with Pirelli General Cable Works. In 1930 he joined the Central Electricity Board (N.W. England area) as acting frequency change engineer, subsequently becoming assistant area transmission engineer and then area transmission engineer. In April, 1948, Mr. Schofield was appointed transmission engineer, North Western Division, of the then British Electricity Authority. In March, 1949, he became transmission construction engineer at headquarters in London, the post he now relinquishes to take up his new appointment.

Another CEGB appointment is that of **MR. P. P. FOWLER,** AMICE, AMIStructE as civil engineer (transmission). From 1934 to 1936 he was employed as an assistant in the drawing office of a firm of reinforced concrete specialists. He left to become a civil engineering assistant with the London Passenger Transport Board. Except for a period of service with the Royal Navy, from 1941 to 1945, Mr. Fowler held this post until 1946, when he was appointed assistant civil engineer with the Ministry of Works. In September, 1954, he joined the then British Electricity Authority as second assistant engineer in the transmission department. Subsequently he became senior assistant engineer, the post he now leaves to take up his new appointment.

DR. JOHN H. MARSHALL, associate physicist with the radiological physics division of the Argonne National Laboratory, has accepted a one-year assignment to undertake research at the Royal National Orthopaedic Hospital, London. With Dr. Hubert A. Sissons, one of the world's authorities on the tissue structure of radiation-damaged bone, Dr. Marshall will study the bone-damaging effects of radiation in animals. He will also visit other laboratories in Leeds, Oxford and London, and in Belgium where scientists are studying radiation damage to bone. The studies are part of a world-wide scientific effort to determine the effects of nuclear radiation on animals and man.

MR. WILFRID J. FRY, AMBritIRE, a director of Solartron Research & Development, Ltd., has been appointed sales director and commercial manager of Solartron-John Brown Automation, Ltd., manufacturers of the Gompertz automatic warehouse with world rights, including the U.S.A., for the Automatic Supermarket. Born in 1927 and educated at Tolworth County School, Surrey, he joined the company that eventually became the Solartron Electronic Group, Ltd. He was the fifth employee and was responsible for many of the early designs of electronic instruments and special products. In 1951 he was appointed senior development engineer and development manager in 1954. When Solartron Research & Development, Ltd., was formed in 1956, he was appointed its manager and joined its board in 1959. He was responsible for the commissioning of the Research Laboratories at Dorking, Surrey, for the Solartron Electronic Group, Ltd., and for the technical administration, design services co-ordination, contract negotiation and financial operation of the research company. In 1959 he was responsible for forming a new division of the group at Farnborough, Hants, which was concerned with analogue computing and industrial data processing equipment, and was also responsible as general manager for all activities, including development and sales. He joined Solartron-John Brown as sales director and commercial manager in July.

SIR GORDON RADLEY, KCB, CBE, PhD, MIEE, formerly director-general of the General Post Office, is to devote part of his time to work with the English Electric Group of Companies, particularly in the development of telecommunication equipment for world markets. Sir Gordon has also been elected a director of three of the group's subsidiary companies:—Marconi's Wireless Telegraph Co., Ltd., Marconi Instruments, Ltd., and the English Electric Valve Co., Ltd. In addition he has been elected to the board of the associated company, The Marconi International Marine Communication Co., Ltd. Sir Gordon was with the Post Office for 39 years, having joined the service in 1920. In 1944 he was appointed controller of research, in 1951 engineer-in-chief, and in 1955 director-general. During his time with the Post Office he controlled the United Kingdom's part in laying the first transatlantic telephone cable, was one of the pioneers of subscriber dialling on the trunk services, and was responsible for the early developments in electronic switching on the telephone services.

Associated Electrical Industries, Ltd., have appointed an additional vice-chairman and made a change in the board of the company. **The Rt. Hon. THE VISCOUNT HEAD OF THORPE,** PC, CBE, MC, has resigned from the board as a result of his appointment as the first High Commissioner in the Federation of Nigeria. Viscount Head became a director of AEI at the end of December, 1957. **SIR JOSEPH LATHAM,** CBE, has been elected a director. Sir Joseph, a chartered accountant, was formerly deputy chairman of the National Coal Board. **MR. C. R. WHEELER,** CBE, has been appointed an additional vice-chairman of the company. He will take up executive duties in 1962.

The appointment has been announced of **MR. G. C. ROBERTS** as commercial director of Fairey Engineering, Ltd. Forty-four years old, he was until recently

Mr. G. C. Roberts

managing director of Britvic, Ltd., and its subsidiary companies and a director of Vine Products, Ltd. Mr. Roberts retains his chairmanship of E. & H. P. Smith, Ltd., general engineers, of Birmingham.

Five new appointments have been made by Atlas Copco (Great Britain) Ltd., of Hemel Hempstead, Herts. **MR. A. HAYES,** formerly chief engineer to Hugh Wood & Co., Newcastle, is now the company's chief sales engineer. Manager of Atlas Copco's mining division is **MR. W. T. JONES,** for the past 3½ years manager of Northern United Colliery, Gloucestershire. **MR. R. MARSHALL,** who until recently was a technical representative in Scotland for Eimco Loaders, is now occupying a similar position with Atlas Copco. From the parent company in Stockholm comes **MR. RALPH NOREN** as manager for stationary compressor sales. **MR. T. M. HORN,** who has retired as manager of the Atlas Copco Leeds branch, is maintaining his contact with the firm in an advisory capacity.

Under a suggestions scheme run by The Morgan Crucible Co., Ltd., **MR. JAMES H. FAIRWEATHER,** a laboratory assistant in the company's research department, was recently awarded £225. His alteration to the cooling system of a laboratory furnace will save approximately 10m. gal of water a year, and represents an annual saving to the company of £400. Mr. Fairweather, who is 57 years old, has been with the company for 21 years.

MR. BERNARD WRIGHT, of John Thompson Instrument Co., Ltd., who joined the company in June, 1958, as their London representative, has been promoted to the position of sales manager. John Thompson Instrument Co., Ltd., is a member of the John Thompson Group and manufactures instrumentation and automatic control systems for steam raising plant and industrial process plant. Mr. Wright began his career with the South Suburban Gas Co., where he served an engineering apprenticeship.

NUCLEAR NOTES

Harwell Library

HARWELL'S new library, opened at the beginning of September by Sir Lindon Brown, CBE, FRCP, contains 20,000 volumes of books and periodicals, 250,000 copies of technical reports, 50,000 microcords and 27,000 pamphlets. Provision is made for coping with a 15 year expansion. New books and reports are estimated to increase at the rate of 4,000 and 30,000 a year, respectively. Careful weeding of the old volumes will keep the increase in manageable proportions. Total floor area of the library building is 40,000 sq.ft, and the estimated cost £200,000. The building is on an H-shaped plan. The whole of the first floor is occupied by the library, which includes catalogue hall and cataloguing department, reading rooms, offices and a translation office. On the ground floor one wing is devoted to library stacks and the remainder is occupied by the document reproduction section. Reference and loan services are provided, not only for Authority staff at Harwell, but also for staff attached to the Establishment from various home and overseas organizations. Staff and visitors to the National Institute for Research in Nuclear Science can also use the library services.

Reactor Conference

ABOUT 250 experts from approximately 40 countries and six specialized agencies of the United Nations participated in the recent international Conference on Small and Medium Power Reactors, organized by the International Atomic Energy Agency (IAEA) in Vienna. This was the first large-scale international conference dealing with this subject matter since the 1958 Geneva Conference. The IAEA has initiated a programme to encourage the development of nuclear power in less-developed countries of the world. The programme provides for surveys of the nuclear power needs of these countries, continuing studies on the technology and economics of power reactors suited to less-developed countries, dissemination of the information thus obtained, and assistance in training personnel. The conference fell within the scope of this programme. Main topics dealt with were: (*a*) Technical aspects of small and medium power reactors (up to about 100 MW electric output) including the present status and future prospects of various reactor systems and concepts; experience gained in the construction, operation and maintenance of existing plants; safety aspects of nuclear plants; reactor fuel cycles, requirements for and training of technical personnel for nuclear power plants; (*b*) Cost evaluation and economics of nuclear power; and (*c*) the role of power reactors in meeting energy demands, particularly in less-developed countries.

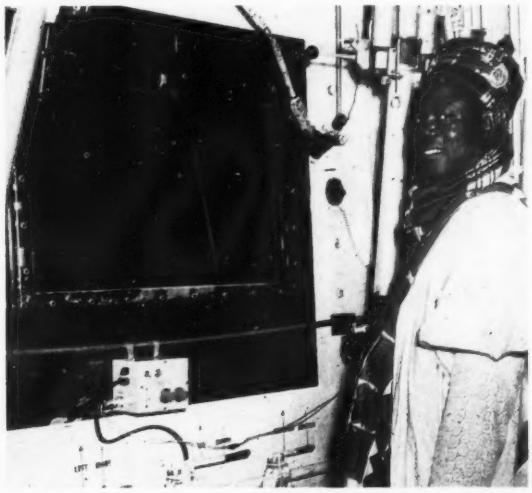
Fuel Contracts

THE U.S. Atomic Energy Commission has ordered nuclear fuels from U.S. General Electric for two of its reactors; 540 plate-type fuel elements will be supplied for the Engineering Test Reactor (ETR) at the National Reactor Testing Station near Idaho Falls, Iowa, and 64 plate-type fuel elements for the Los Alamos Omega West reactor. GE will also supply 126 control elements for the ETR. The ETR is operated for the AEC by the Phillips Petroleum Co., and GE recently completed an earlier order from Phillips for 1,140 fuel elements and 272 control elements for the ETR.

Reactor for S. Pole

PM-3A is the designation of a 1,500 kW reactor to be built by The Martin Co., in the Antarctic, at the U.S. Naval Air Facility at McMurdo Sound. This is the principal base of operations for all U.S. scientific efforts in the Antarctic. It can be reached by ship for only a few months each year; and the complement of nearly 500 men during the Antarctic summer drops to about 130 during the winter when all supplies must be delivered by air. PM-3A is expected to offer major savings to the U.S. Navy over many years. About 80 per cent. of all air and ship transportation to Antarctica now pertains to fuel oil for diesel power plants, and the delivered cost of the fuel oil has been estimated at from $1 to $3 a gal. The reactor core, about the size of a single 55-gal drum, will power the plant for two years, doing the job of millions of gallons of high-grade fuel oil. Government-sponsored studies estimate that the savings will pay for the higher initial cost of the plant in a few years, and that additional millions of dollars will be saved subsequently during the 20-year life of the plant. Delivery of the reactor is scheduled for November, 1961. Because the plant can be installed only during the Antarctic summer, delivery of a fully-tested unit, ready for shipment in 15 months can mean a full extra year of operation at McMurdo Sound. The company is building another packaged nuclear plant called PM-1, which will go into operation next year at a U.S. Air Force radar station in Sundance, Wyoming. There, the restrictions on construction imposed by weather are similar, though not as severe as in the Antarctic; and the plant is being prefabricated by Martin in Baltimore in "packages" which can be joined at the site. Like PM-1, the new power plant will be built in sections which can be carried by aircraft if necessary, although delivery of the first plant to will be by sea transport.

Nigerian Premier at O.R.N.L.



Recent visitor to the Oak Ridge National Laboratory, Tennessee, U.S.A., was Sir Ahmadu Bello, Prime Minister of Nigeria. He is seen here at the window of a hot cell in the Isotope Division. Oak Ridge is operated by Union Carbide for the U.S. Atomic Energy Commission

B. & W. Report Test

THE Babcock & Wilcox Co., designer and supplier of the major reactor components for the research marine reactor for the Kernenergie Hamburg, Germany, have reported that the test reactor has successfully reached its full rated power of 5,000 kW. Consisting of a reactor core and four special-purpose pools, the unit is the largest of its type ever built. According to spokesmen for The Babcock & Wilcox Co., it is also the first European reactor to be built expressly for research in marine applications. Owned and operated by Gesellschaft Fur Kernenergie-verwertung In Schiffbau Und Schiffahrt (The Society for the Utilization of Nuclear Energy in Shipbuilding and Navigation) the research unit is 89 ft long and 29 ft wide. It is unique in that it has four pools—built in series—instead of the more conventional double pool.

Test Assembly for M.G.C.R.

The honeycomb structure of this low power nuclear assembly will enable scientists and engineers to study the physics of a great variety of fuel and moderator arrangements. The assembly is in the laboratories of the General Atomic Division of the General Dynamics Corporation at San Diego and is being used for investigations into the Maritime Gas-Cooled Reactor (MGCR) General Atomics are developing for the U.S. Atomic Energy Commission and the Maritime Administration

Seed Irradiation

THE beginning of "a new and better understanding and of a new and better approach to the problems of cellular radiobiology" was how Dr. Arnold R. Sparrow, of the Brookhaven National Laboratory, U.S.A., described the IAEA-FAO Symposium on the Effects of Ionizing Radiation on Seeds. In his summing up he said it seemed that almost general agreement could be reached on the fundamental role of chromosome breakage in radiation genetics and in plant radiation biology. The study of chromosome breakage or damage might also throw light on how evolutionary changes had occurred and lead to better methods of mutation breeding and might even allow prediction of the radiosensitivity of organisms not previously studied. This, he said, would also have considerable practical value in saving much time for anyone starting work on new species. Dr. Sparrow urged that intensified research should be undertaken both on chemical mutagens and nuclear radiation in mutation breeding and he suggested that a small group of the most experienced experts draw up a list of specifications to be followed in seed irradiation experiments. Radiation as a research tool, he said, "has become a serious business" which it is no longer "appropriate or profitable for amateurs to play with." Dr. Sparrow also said he hoped that some of the contributions made at the Seminar might have "applications outside the field of plant breeding or even of plant science" as for instance in cell physiology, ecology, health physics or even in medical uses of ionizing radiation. The symposium was held at Karlsruhe, Germany, and was organized jointly by the International Atomic Energy Agency and the Food and Agriculture Organization of the United Nations, in co-operation with the German Kernreaktor Bau- und Betriebs- Gesellschaft. There were approximately 100 participants from 23 countries and 53 scientific papers were presented and discussed.

Stress Committee

A JOINT British Committee for Stress Analysis has been set up to represent the interests of Great Britain at the periodic meetings of the Permanent Committee which are held in Europe and thus ensure adequate British participation in International conferences on field of stress analysis. The principal object of the permanent committee, membership of which is open to all West European countries is the furtherance of international collaboration in the field of stress analysis, and in seeking to achieve this end international conferences will be arranged at four-year intervals. Such conferences will normally be phased with the International Congress on Applied Mechanics. The officials and secretariat of the permanent committee will normally be appointed by the national committee in whose country the next international conference is due to be held. The Joint British Committee consists of representatives appointed by The Royal Aeronautical Society, The Institution of Civil Engineers, The Institution of Electrical Engineers, The Institute of Marine Engineers, The Institution of Mechanical Engineers, The Royal Institution of Naval Architects, The Institute of Physics, and the Physical Society, The Institution of Structural Engineers and the Institute of Welding. Mr. A. F. C. Brown, of the National Physical Laboratory, and the representative of the Institution of Mechanical Engineers, has been elected first chairman of the committee, and The Institution of Mechanical Engineers provides the secretariat.

Studying Radiation

AN artificial skeleton, encased in plastic to simulate a man, is being exposed to radiation bombardment at Lockheed's Georgia Nuclear Laboratories near Dawsonville to determine the protective value of various shieldings against bodily organ and bone marrow damage. These studies of various radiation dosages on the human system are sponsored by the U.S. Army Medical Research Laboratory, Fort Knox, Kentucky, which has awarded Lockheed a $12,000 contract for the experiments. The Army research laboratory has supplied the "mannikin," whose plastic bones and organs contain fluids of comparable density to those of a human being. Lockheed scientists have filled the "body" with sensitive measuring instruments in all vital organs. Shielding of various compositions protect certain bone structures, while others are completely exposed, enabling scientists to measure relative bone marrow damage accurately. The tests are expected to continue for several months. Following completion of the tests and their evaluation the "mannikin" will be returned to Fort Knox for further evaluation by U.S. Army medical men.

Versatile Reactor

THE UKAEA have signed a construction contract with Fairey Engineering Ltd., and a control gear design contract with H. M. Hobson Ltd., in connection with a new zero-energy oscillator reactor which is to be built at the Atomic Energy Establishment, Winfrith. The reactor, which will be called HECTOR, (Heated Experimental Carbon Thermal Oscillator Reactor) has been designed expressly to facilitate the use of the "Pile Oscillator" technique for evaluating the nuclear behaviour of fuels, moderators, and structural materials in reactors. This technique, which utilizes small samples has been highly developed by the UKAEA to further the reactor physics aspects of power reactor development. HECTOR is expected to go critical during 1962. HECTOR possesses a unique feature, in that it is possible to reproduce closely the conditions appropriate to many different designs of power reactors. It is believed to be the world's first reactor in which oscillator measurements can be made in such a wide range of conditions. The reactor core will be an annulus of graphite and highly enriched uranium/aluminium alloy within various assemblies of fuel and moderator may be constructed around a central tube. The sample under investigation will be cycled through this tube, producing oscillations in reactor power level from which the nuclear behaviour of the sample, under the conditions reproduced by the assembly can be determined. Since the fuel material in the assembly may be natural or enriched U-235. plutonium, thorium, U-233 or irradiated elements from power stations, and since the assembly can be heated to 450°C., it is possible to investigate samples under the conditions to be found throughout the life of many different designs of power reactors.

NUCLEAR NOTES

Lear Contract

THE Industrial Products Group of Lear, Inc., has received a contract to produce ten remotely operated automatic control systems for nuclear reactors being developed by Martin's Nuclear Division at Baltimore.

New Premises

NEW works and offices have been opened by Henry Hargreaves & Sons Ltd., the light and sheet metal engineers, of Bury, Lancs. Adjacent to the premises previously used by the company, the new buildings contain two manufacturing bays each with about 10,000 sq.ft of floor space. Henry Hargreaves have been associated with many nuclear energy projects including work at Capenhurst, Calder Hall, and Chapelcross, Dounreay, Springfields and Windscale.

Officially Approved

SIEBE, GORMAN & Co., Ltd., have announced that their Mark 4 compressed air breathing apparatus has been granted the approval of Her Majesty's Chief Inspector of Factories under the Chemical Works Regulations, 1922. The apparatus has been supplied to several fire brigades and also to the U.K. Atomic Energy Authority.

Prototype BWR

GENERAL ELECTRIC, of New York, are to design, build and test a single-cycle forced circulation boiling water reactor for its prototype nuclear power plant near Los Angeles, California. General Electric will also provide the first fuel load and will provide operator training under a fixed price contract with the AEC. The plant will be operated by the Los Angeles Department of Water & Power and the Pasadena Municipal Light and Power Department, who will provide the turbine-generator facilities and purchase the steam produced by the reactor.

Talking Plans

THREE large scientific conferences and 15 symposia have been scheduled by the International Atomic Energy Agency from October 1st, 1960 to the end of 1961. The schedule, which in some parts is still provisional, particularly as to the exact places and dates in 1961, is as follows:—Neutron Pile Research (Symposium, Vienna, October 17th-21st, 1960); Diagnosis and Treatment of Acute Radiation Injury (Symposium, Geneva, October 17th-22nd, 1960); Chemical Effects of Nuclear Transformation (Symposium, Prague, October 24th-27th, 1960); Education and Nuclear Energy (Regional Symposium, Argentina, November 7th-11th, 1960); Nuclear Ship Propulsion with Special Reference to Safety (Symposium, Italy, November 14th-18th, 1960); Pest Control by Radiation (Symposium, India, December 5th-9th, 1960); Use of Radioisotopes in the Study of Endemic and Tropical Diseases (Regional Symposium, Bangkok, Thailand, December 12th-16th, 1960); Detection and Use of Tritium in the Physical and Biological Sciences (Symposium, Vienna, January, 1961); Nuclear Electronics (Conference, April-May, 1961); Controlled Thermonuclear Fusion (Conference, May-June, 1961); Whole Body Counting (Symposium, May, 1961); Pre-treatment of High Level Radioactive Wastes (Symposium, May, 1961); Radioisotopes in the Biological Sciences (Conference, July-September, 1961); Effects of Ionizing Radiation at the Molecular Level (Symposium, June, 1961); Fast and Intermediate Reactors (Symposium, August, 1961); Power Reactor Experiments and Tests (Symposium, October, 1961); Radiation Damage in Solids and Reactor Materials (Symposium, autumn, 1961); Programming of Research Reactors (Symposium, autumn, 1961).

Getting to Jupiter

PROPOSALS for a deep space vehicle operating under full thrust for the two years necessary to carry it to the planet Jupiter, with enough residual power to operate its instruments for several years thereafter, have been disclosed by a Lockheed missiles and space division scientist. Speaking before the Institute of Astronautical Sciences in Stockholm, Dr. R. H. Olds described a nuclear-thermionic-ionic propulsion system to provide a continuous power supply by direct conversion of heat to electricity. The entire system, designed without any moving parts, will operate unattended in space with little likelihood of failure. "The key to the whole system," said Olds, "is a series of small nuclear reactors about 2 ft in diameter producing 1,200°C. temperatures to banks of thermionic generators which convert the heat directly into electrical energy for the ion beam motors." Dr. Olds proposes the use of caesium vapour as fuel for the motors. "With such a system, 110 lb of propellant would be capable of delivering an equal weight of payload to Jupiter," said Olds. "Small as the reactors are, they will still only use about one-tenth of 1 per cent. of their energy potential, thus the vehicle will have several years of reserve power after arrival at the planet."

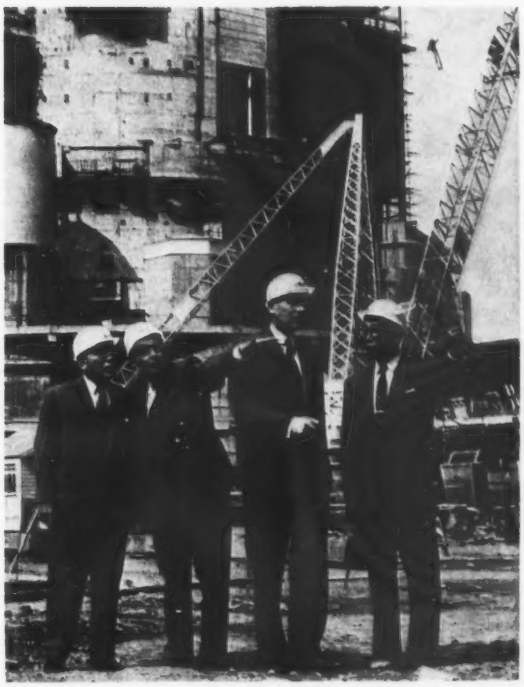
U.S. Irradiations

GRAPHITE irradiation is to be carried out for the North Rhine-Westphalia Institute for Reactor Materials, Germany, by General Electric of New York. The Institute is studying the use of several types of graphite as possible moderator or reflector material for different types of reactors. General Electric will irradiate the graphite at various temperatures and neutron fluxes in their reactor at Vallecitos, California.

Nearly Completed

THE 132-kV switching station associated with the South of Scotland Electricity Board's nuclear power station at Hunterston, and completely equipped with AEI switchgear, is now at an advanced stage of erection. As a protection against the high degree of local atmospheric salt deposit, the station has been built indoors. Standard outdoor equipment has been used, and with the compact design of the circuit-breakers and the special arrangement of the busbars and isolators a notable space-saving layout has been achieved.

Visitors to Hunterston



Mr. K. Ohno, Japanese Ambassador to Britain, is shown over the nuclear power station being built by the General Electric Co., Ltd., for the South of Scotland Electricity Board at Hunterston, Ayrshire. He is seen here with Mr. D. Angivin, resident engineer, Mr. R. N. Miller, GEC director, and Mr. S Tamiya, scientific attache at the Japanese Embassy

NUCLEAR NOTES

Document Guide

THE United Kingdom Atomic Energy Authority has published a revised edition of its "Guide to UKAEA Documents." The first edition, issued in 1958, was quickly exhausted, and it has been out of print for some time. From the worldwide requests received, it was soon clear that there was a much wider public for the Guide than had been forecast, and it was decided to place the second edition on open sale. As now presented, it has been almost completely rewritten. The Guide explains to the public how the Authority publish information about their research, development, design and other work and where new publications are announced; how the Authority is organized into various autonomous groups, and by which of their establishments information is published; and where the public can obtain free access to read the publications—at depository libraries in Great Britain and 36 foreign and Commonwealth countries—or where they can buy them. A good deal of background information about various series of technical reports, from the early days of the Ministry of Supply, is also given for the many libraries with collections of them.

Among the new features of this edition are details of a sales service of scientific and technical reports, operated by the Authority, whereby the public may place standing orders for those on particular subjects; a further sales service operated by a Wakefield firm under contract, which provides micro-copies of older or out of print reports; and a list of bibliographies of atomic energy literature, compiled by the groups' libraries, available to the public. Copies may be purchased from H.M. Stationery Office or from any bookseller at 1*s.* 6*d.* net.

Resistance to Radiation

THE world's oldest living things, the giant sequoia trees of California, have provided new evidence of the living cell's resistance to long-term radiation. This statement was made by an Argonne National Laboratory scientist at the recent meeting of the Radiation Research Society in San Francisco. Dr. Theodore N. Tahmisian, of Argonne's Division of Biological and Medical Research, stated that experimental evidence gained from the sequoias provides additional proof that within the living cell there is a mechanism that can cope with radiation in small amounts. With the aid of forest rangers from Yosemite, General Grant, and Sequoia National Parks, Dr. Tahmisian gathered seeds from the oldest giant redwood (*sequoia gigantea*) trees. Among the trees selected were such well-known tourist attractions as the General Grant and General Sherman trees. These trees are from 2,000 to 4,000 years old. The aim of this investigation was to determine if natural radiation for such a long period of time would affect the viability of the seeds or would introduce abnormalities during the process of cell division. Natural radiation, present everywhere, comes from cosmic rays and from small amounts of radioactive materials such as radium that occur in the soil. Estimates of cosmic radiation at an altitude of 7,000 ft (70 mr/year) were taken from standard Atomic Energy Commission tables. Radiation from the soil was determined by Sarmukh S. Brar, Argonne physicist. He determined the radioactivity of water, surface soil, deep soil, rocks, and organic matter from the redwood groves. It was determined that the roots of the redwoods receive approximately 150 roentgens of radiation every 1,000 years; the cells of the trees 250 ft above ground, where the seeds are harvested, get 115 roentgens/1,000 years. (The average human receives 10 or 15 roentgens of natural radiation in a 60-year lifetime.) Natural radiation levels in the redwood groves were found to be no different in intensity than levels in other locations at the same altitude. Dr. Tahmisian brought seeds from the redwood trees to his laboratory at Argonne, where he germinated them and examined them under the microscope. Seventy per cent. of the seeds germinated, but more interesting, he said, was the fact that his observations indicated normal cell division and normal chromosomes.

EPOXY RESIN LAMINATE

(*Continued from page 476*)

was pushed through the heated loop, the core was cut to exact cross-section and curvature.

Since the foam was too porous for a mould, its surface was filled with plaster of Paris and smoothed carefully. After the plaster dried it was sanded lightly. A silicone-base release agent was rubbed into the plaster, when wiped off until only a thin layer remained.

Next, a laminating resin was prepared by mixing Shell Chemical Co.'s Epon* 820 resin with 9 per cent. diethylenetriamine curing agent and adding 4 per cent. by weight of Cab-O-Sil. This produced a thixotropic compound—that is thick enough to prevent run-offs and yet fluid enough to assure that the segment would have a smooth interior surface without voids. This resin formulation was applied to the core and allowed to set for 3 hr. Then the coated cores could be handled.

An uncracked piece of the original cast epoxy segment was salvaged and tested for strength against vacuum. It collapsed. This finding convinced us that an evacuated epoxy segment could not withstand atmospheric pressure unless it had a fibrous reinforcement against flexural stresses. The obvious choice was fibreglass.

**Registered*

Applying the Coats

A layer of glass cloth was cut to fit closely, with a small overlap over the coated cores. The layer was saturated with the same resin mixture and applied. Successive layers were saturated and applied, with the overlaps on alternate sides to assure equal wall thickness, until the laminate was $^{3}/_{16}$ in. thick. Each coat of resin was allowed to set for several hours before a fresh layer of cloth and resin was applied. Heat lamps in the general area raised the ambient temperature and speeded up setting time. When the lay-ups were complete, the laminate was cured for 24 hr.

The polystyrene foam core was removed easily enough—a cup of acetone poured on the core completely dissolved it. The thin layer of plaster of Paris remaining inside the laminate was shaved off and the release agent was washed out. Then the inside surface of the laminate was coated with a low-conductivity silver paint to bleed off electrical charges that might accumulate on a non-conducting surface.

As the cross section of the laminated segment did not exactly match the oval of the adjacent quartz segments, case epoxy adapters (or transition pieces) were used to fit them together. An adapter was bonded to each end of the laminated segment with a layer of glass cloth embedded in the resin to provide necessary strength. The joint between the epoxy and the quartz was made with ozone-resistant neoprene.

Ports, windows and other openings are easily provided in a reinforced epoxy resin segment. The segment can be milled, sawed, filed, drilled, or sanded. For example, a circular port can be made in the laminate to match the standard port system on the quartz vacuum tank segments. Such ports permit insertion of equipment into the vacuum system. Equipment is mounted on flanges that are bolted up to the ports against vacuum-seal gaskets.

Equipment and Materials

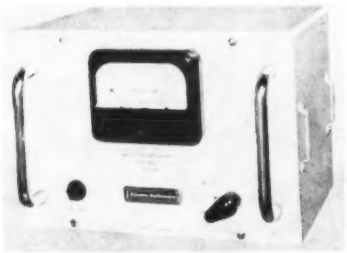
Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Laboratory Aid

Unicam Instruments, Ltd., have introduced a new infra-red spectrophotometer, which in the hands of the organic chemist should play an important role in any programme involving chemical analysis. For routine work, the simplicity of operation and special design features make possible the delegation of time-consuming work to general laboratory staff, freeing others for more important duties. Only one operating control is used when the instrument is set up. The SP.200 as it is called is at once a very accurate and easily operated infra-red instrument. Long-term reliability has been a feature of the design, and its low cost opens up the field of infra-red analysis to a wide section of science and industry previously unable to justify this most powerful technique. **(OCT 1)**

Background Monitor

A new lightweight portable monitor has been designed and developed by Plessey Nucleonics, Ltd., of Northampton, for the measurement of background radiation.



Plessey's new background monitor—the PN 1072

This monitor, known as Type PNI 1072, has been designed to fill the frequent need for an accurate means of measuring any background activity quickly and easily. Detection is accomplished by a built-in halogen-quenched Geiger Muller tube with measurement on a transistor ratemeter giving direct reading of dose rate on a 2½ in. scale moving coil meter. The instrument has a range of from 0 to 3 milliroentgens/hr on a two decade quasi-logarithmic scale, with a minimum scale calibration of 30 microroentgens/hr. The unit is powered by a 9v dry battery and weighs only 8 lb. **(OCT 2)**

Silicone Rubber

ICI have placed on their sales range the first three of their "Silcoset" silicone rubbers. These new products can be cured at room temperature and, because of this remarkable characteristic, can be used in circumstances where ordinary silicones (needing high curing temperatures) cannot be employed. Curing is executed by the addition of one of two catalysts which are supplied with the product, and the curing time can be varied to suit the needs of the user. "Silcoset" rubbers are excellent for sealing, patching, caulking and potting applications where extremes of temperature are ultimately to be encountered. It is suggested they are used for moulding silicone rubber parts where heat curing is undesirable, or when the cost of conventional rubber moulding equipment is not justified. Encapsulation of delicate electronic parts—"fly in amber" protection—is readily done with "Silcoset." Moulds for casting resins used in model reproduction and for low cost tooling can be easily made from "Silcoset" rubbers, which have the ability to reproduce the most intricate details in moulding processes. When dissolved in a special solvent, "Silcoset" rubbers can be effectively used to coat an extensive range of organic and inorganic fabrics for use in electrical insulation and anti-stock applications. **(OCT 3)**

Made in conjunction with the UKAEA is this new portable radiation detection supplied by Plessey Nucleonics

Beryllium Monitor

In conjunction with the UKAEA, Plessey Nucleonics, Ltd., have produced a portable radiation monitor, designed for comfortable transportation by two men, capable of detecting beryllium in an aggregate containing less than 0.01 per cent. BeO. A gamma source housed in the equipment irradiates the sample and neutrons subsequently released by the beryllium are slowed down in an oil tank where they are detected by proportional counters. Transistorized, shockproof and impervious to extremes of temperature and humidity, the equipment is powered by eight U2 type dry cells stored in the monitor. The sensitivity is such that 0.004 per cent. BeO doubles the normal background rate.

Cut along here

To: NUCLEAR ENERGY

147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT & MATERIALS *feature for October, 1960*

Item No's ....

....

IS THIS ENQUIRY CONFIDENTIAL? YES | NO

Enquirer's Name .....

Position .....

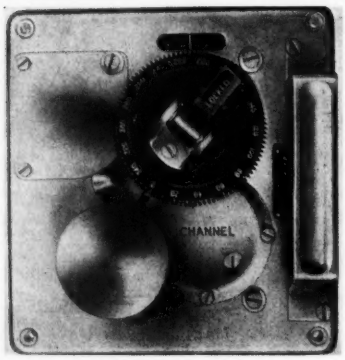
Firm .....

Address .....

Two adjustable carrying handles are fitted to the instrument to ensure that the operators are not over-exposed to irradiation. Shielding is also provided within the equipment and a display unit is mounted in a position convenient for one of the operators. **(OCT 4)**

Remote Actuator

A remotely controlled device with applications in many fields where it is required to rotate a shaft with a high degree of accuracy has been developed by The Plessey Co., Ltd., in conjunction with the Ministry of Supply for use with multi-channel transmitters and receivers. The Plessey unit, which is designed to rotate a



Rotary position selector unit made by Plessey Co., Ltd.

shaft to any one of 12 positions, each position being set up independently, with an accuracy of within 6 min of arc, is available for 12-48v d.c. operation in two panel sizes (4 × 4 in. or 3½ × 4⅛ in.) and with a torque of either 35 oz-in. or 60 oz-in. Visible indication from the front of the unit shows the selected position and a built-in switch can be used for confirming the position to the remote control site. A further built-in switch allows a number of selector units to be operated in sequence. **(OCT 5)**

Trace Shifter

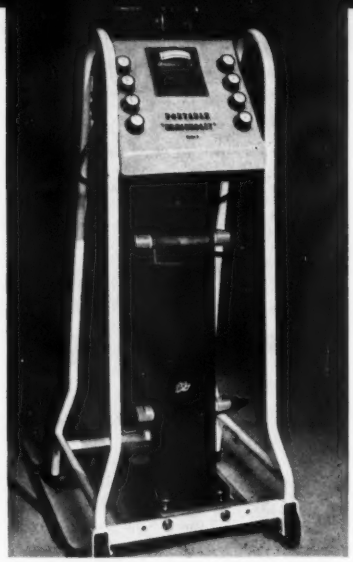
Cawkell Research and Electronics, Ltd., have introduced a new instrument designed to allow the user of an oscilloscope to display, in sequence, up to ten signals coming from the same source. Each signal is displaced vertically relative to its predecessor so that comparison may be made. This Trace Shifter finds its main application in conjunction with transient storage oscilloscopes, such as the Remscope, and with its aid cycle-by-cycle variations in a recurring signal or a series of transients may be studied. The interval between successive signals is unimportant as the Shifter is triggered at the end of the oscilloscope time base. It is suitable for use with almost any oscilloscope with differential inputs. The unit is self-contained, battery operated and uses transistors. **(OCT 6)**

New Filter Housing

Special feature of a new filter housing by Micro Metallic Division of Pall Corporation, New York, is a design that permits the bowl to be removed from the pipeline without disturbing the pipe connections. The container design permits fabrication in a wide variety of materials with maximum cleaning ease and accessibility to all fluid passageways. The housing is generally furnished in type 304 stainless steel or, on special order, in an alloy to match the porous stainless steel standard elements. Corners are rounded, where possible, both inside and outside. A quick-opening closure makes removal of the bowl and replacement of the element a matter of seconds. Housings can be designed to withstand up to 10,000 lb/sq.in.; 125 or 300 lb/sq.in. gauge is standard. Elements can be supplied of PSS porous metal for use with or without a filter aid, as cylinders, bayonets, stars or in special types such as Rigimesh corrugated sintered woven wire mesh. Filtration ratings of elements range from 2 to 55 microns, nominal (98 per cent.), with absolute ratings as low as 15 microns available with certain types of elements. **(OCT 7)**

For Demineralizing

The newly introduced Mark 6 portable "Deminrolit," designed and manufactured by The Permutit Co., Ltd., can convert up to 12 gal/hr of clean cold water into demineralized water having a conductivity of less than 1.0 reciprocal megohm/cm. This is the quality of water produced by the unit and conforms to the "Purified Water" standard of the British Pharmacopoeia, 1958. The new unit is a mixed bed ion exchanger. The ion exchange materials

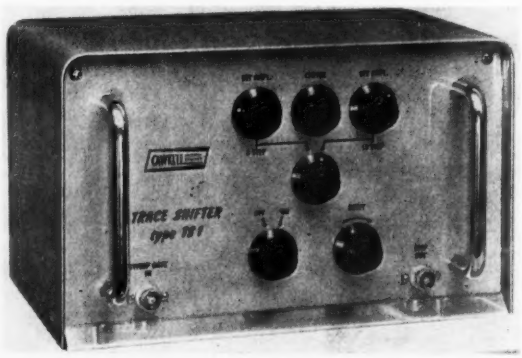


This portable water demineralization plant is manufactured by the Permutit Co., Ltd.

used are "Zeo-Karb 225" and "De-Acidite FF," manufactured by Permutit at their chemical production division in South Wales. The equipment is designed for simple and reliable regeneration on the spot. A conductivity tester is fitted which continuously monitors treated water quality. Constructed as a free-standing unit of robust, non-corrodible construction throughout, the Mark 6 portable "Deminrolit" is suitable for workshop as well as laboratory conditions. No expensive plumbing is necessary, the unit being simply connected by flexible hose. **(OCT 8)**

Level Monitoring

Present-day manufacturing processes call for accuracy and speed of measurement where the contents of tanks, silos, hoppers and similar type containers are concerned, even manometer tubes, if production and safety, too, are not to be jeopardized. Electronic Machine Co., Ltd., by the introduction of their "Contimitor," have produced an instrument which they claim not only to be economical to buy, but is also an extremely sensitive piece of equipment. It is a capacity operated monitor which provides a continuous indication of level on a meter or recorder and it owes its excellent stability and freedom from drift to a unique circuitry which employs a crystal oscillator with full temperature and mains compensation. A matched transmission line connects the instrument to its probe or transducer and cable lengths of up to 100 yd can be confidently used without loss of stability. A capacity change of 10 pica farads will give a reading over a range of nil to full scale on a 1 milliamp meter, or a voltage change of 5v is available. In cases where extreme sensitivity is required provision can be made to give .03 pica farads for 1 milliamp change in output. If it is used in applications such as continuous level monitoring in tanks, where high minimum values of capacity are encountered, with relatively large changes in capacity as the level rises, provision is made for tapping down the coil at the probe end, thus a wide range of probes or transducer conditions can be accommodated. **(OCT 9)**



Cawkell's Trace Shifter TSI

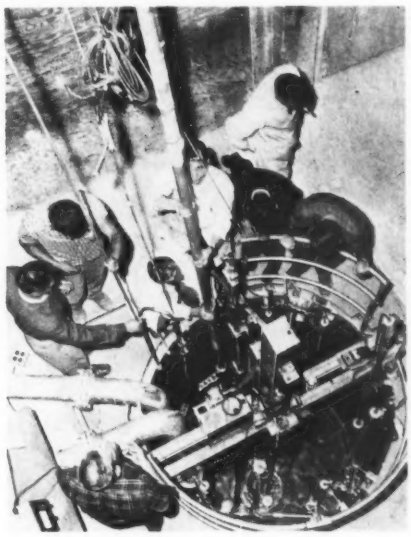
ISOTOPE WORLD

A Supplement devoted to the Subject of Radioisotopes

DIRECT POWER PRODUCED

Caesium Cell in Reactor

NINETY watts of electric power were recently produced direct from the heat of nuclear fission in the TRIGA reactor at General Atomics' John Jay Hopkins Laboratory, San Diego, California. The power was generated in a caesium cell thermionic converter containing a nuclear fuel element made of uranium carbide and zirconium carbide.



Lowering the caesium cell thermionic emitter element into the core of the TRIGA reactor

Broad Research

General Atomics, a division of the General Dynamics Corporation, are carrying out a broad research and development programme in direct conversion which is supported by the Rocky Mountain Nuclear Research Group, a consortium of eight utility companies. The TRIGA test was part of this programme.

Robert C. Howard, a General Atomics engineer, describing the results of the test at a meeting of the American Institute of Electrical Engineers, said that the 90w were produced at a power density of 21w sq.cm delivered into an external load. The conversion of fission heat into electrical energy, as measured at a busbar outside the reactor during the test, showed overall efficiencies as high as 10 per cent. at an operating temperature of about 3,500° F.

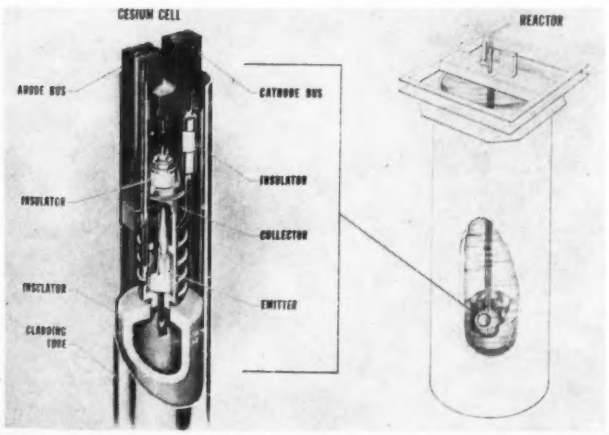
Mr. Howard described the test as the first step in a series of experiments aimed at establishing the feasibility of a nuclear-thermionic reactor system for both space and land-based power applications. He said the tests were significant in that they showed the caesium cell converter to be capable of producing electric power at high power densities and at adequate voltages, within an actual reactor environment. He also said the caesium cell appears to be capable of further increases in efficiency when its dimensions and temperatures are optimized, and that it also has the capability for ultra high temperature operation.

Over 12 cycles totalling several hours of operation at temperatures ranging from room temperature to incandescence were conducted during the test series, Howard said. "No attempt was made to utilize waste heat rejected by the converter, to further increase the overall electrical output and efficiency."

Enriched Uranium

The caesium cell thermionic-emitter element used in the reactor tests utilized fully enriched U-235 and was made by a carbide fabrication technique developed by General Atomics. In the caesium cell, electrons are "boiled out" of the emitter by the heat from the fissioning of the uranium and are collected by an electric current collector, which surrounds the emitter electrode. Caesium vapour present in the gap between the emitter and the collector is used to enhance the rate of power production.

The entire assembly was housed in an aluminium cladding tube identical to that which normally houses a regular General Atomics TRIGA research reactor fuel element. Two heavy electrical conductors were used to deliver the electric power from the caesium cell to an instrumented load at the top of the reactor pool.



Section through the caesium cell and a drawing to show its position in the reactor

Martin Isotope Appointment

DR. CHARLES E. CROMPTON, one of the pioneers in the chemistry of heavy "man-made" elements, has been appointed director of the advanced development section in the isotopic power department of The Martin Co's nuclear division. Dr. Crompton was a member of the original plutonium research group at the University of California and has had over 17 years' experience in this field with both Government and industry. At Martin he will direct and co-ordinate all research on advanced applications of radioisotopes as a source of heat and electricity. Dr. Crompton was born in 1922, in the Pribilof Islands in Alaska. He received his BSc degree with honours from the University of California in 1943, and continued his studies at Washington University under Dr. Joseph Kennedy, one of the co-discoverers of the element plutonium. He received his PhD from the University of Tennessee in 1949.

Following his undergraduate work at Berkeley, he joined the small group of scientists there who were developing some of the early processes for recovering plutonium. Later he directed studies of uranium chemistry, alpha particle ranges, and isotope enrichment for the Manhattan Project; and in 1949 he joined the isotopes division of the U.S. Atomic Energy Commission. He served as deputy director of the division, dealing with radiological safety and licensing, and with the production and distribution of radioisotopes for industrial and scientific use. At the beginning of 1956 he left the AEC to join the National Lead Co., of Ohio, where he was concerned with the chemical and metallurgical aspects of nuclear fuel element production.

T.U.C. Course

ABOUT 40 trade union officials have been attending a four day course on the industrial uses of radioisotopes held at the UKAEA Isotope School, Wantage. The course included a programme of lectures, discussion and visits. Special attention was given to health and safety aspects of the use of isotopes.

400,000 ISOTOPIC TREATMENTS A YEAR

Results of Medical Survey in U.S.A.

THIRTEEN years after the first despatch of radioisotopes made by the U.S. Atomic Energy Commission for medical purposes in August, 1946, the office of Isotopes Development of the AEC sponsored a search into the effect on these new substances on the practice of medicine and into their frequency and type of use. They also requested knowledge as to where and by whom they have been used and asked for indications concerning future use, etc.

These investigations were carried out over a period of a year by the Stanford Research Institute, California, in various hospitals, clinics, laboratories, and physicians' offices throughout the United States.

In general, it was found that the use of radioisotopes in medicine had become widespread. About 400,000 administrations are given to humans annually; 85 per cent. of these are for diagnosis. Twenty different isotopes are used, with radioiodine being by far the most common. Others commonly used include radiophosphorous, cobalt-60, and chromium-51.

An average of three out of every 1,000 patients in clinics or hospitals undergo some type of diagnosis or therapy involving radioisotopes. This is about the same number as those who have fractures, appendectomies, or hernia repair. The number is more obviously significant when one considers that radioisotopes are chiefly used for relatively infrequent conditions—endocrine disorders and cancer.

Threefold Increase?

Over 1,000 general hospitals in the United States offer radioisotope services, and they are also used in clinics and physicians' offices. At present over 40 per cent. of hospital patients are in institutions offering these services.

It is expected that these numbers will increase. A fairly comprehensive clinical radioisotope programme can be equipped for $7,000 to $10,000, which is within the range of most institutions that could make practical use of a programme. The number of institutions using radioisotopes may well triple by 1965. Further, the numbers of physicians trained to use these new tools could increase as much as fivefold in the next ten years.

The study also considered Co60 teletherapy units. It was found that such units or supervoltage X-ray units are located in medical service areas that contain two-thirds of the radiation specialists and over half the population. Projections on the number of units likely to be used in the future were made on the basis of cancer and population trends.

About 300 institutions are carrying on medical research with radioisotopes. Some 2,000 separate projects using well over 100 different isotopes, are in progress. This represents over 10 per cent. of all health research projects in the United States supported by the federal government or national foundations.

The coming trends in radioisotopes cannot be predicted with precision because (1) there are no historical trends to analyse and (2) any of a number of possible future applications could grow to exceed all current uses. The project team noted however, that the volume in the United States of current uses alone could grow to 700,000 administrations a year, if urban use-rate of isotopes were to become standard for the nation as a whole. Research in the field should also increase, leading to new uses.

Current health research investigations show potential applications in conditions far more frequently encountered than those providing bases for current applications. For example, studies of insulin metabolism using radioisotope-tagged insulin may provide important clinical data on diabetes. *In vitro* tests with radioisotopes are being studied for determining immunity to various contagious diseases, and these might find wide application for children. Or, another example, tests with radioisotopes may contribute to diagnosis of certain mental illnesses associated with metabolic disorders.

If only one of these were to find acceptance, considerably more than 700,000 annual administrations might well be expected in coming years.

Sensitive Leak Detection

U.K.A.E.A. Methods Exhibited

A METHOD for detecting leaks at a rate of less than one sixty millionth part of a cu.in. a day was illustrated in the United Kingdom Atomic Energy Authority's exhibit at the recently held 5th International Instruments and Measurements Exhibition in Stockholm. The method, which uses a radioisotope technique. was developed at the Wantage Research Laboratory.

Corresponding to a cube of about one four-hundredth of an in. side, a sixty millionth of a cu.in. appears to be a very small volume, yet it can contain seven million million atoms of the radioactive gas used in this particular application.

Easy Detection

Since initially, some 16,000 of these atoms would decay and emit tell-tale radiation each second, detection of their presence and calculation of the rate of leakage can be carried out with comparative ease.

To determine the rate at which leaks in sealed components would admit air or other gases, these are immersed in an atmosphere of radioactive krypton-85 gas which is raised to a known pressure for a fixed period of time. After the components have been removed from the gas, the amounts of krypton which have found their way into the objects under test are determined by measuring the emitted radiation with a counter.

For outward leakage, the component is filled to the required pressure with a known specific activity of the gas. Then, either the escaping gas is collected and assayed with a counter, or measurements are made of the decrease over a period of time in the intensity of radiation emitted from the component. The latter is the most reliable method as a leak can become temporarily blocked.

Tests of small articles such as transistors—whose life is shortened if oxygen or water vapour penetrates their containers—are best made by immersing them in the gas. Sensitivity is reported to be about 100 times better than with a helium mass spectrometer.

HIGH ACTIVITY SOURCES ON SALE

Opportunity for Quicker Radiography

COBALT-60 sources for radiography with the extremely high specific activity of 100 curies/gm are now being prepared by Atomic Energy of Canada Ltd., and are available in the United Kingdom through the industrial division of Watson & Sons (Electro-Medical) Ltd., of Wembley, Middlesex.

These sources are made up from nickel plated, cylindrical pellets of cobalt measuring 1 mm × 1 mm, which are double sealed in welded stainless steel capsules.

The main advantage of this high specific activity material is that the sources prepared from it have extremely small physical dimensions for their output. This enables sharper radiographs to be made or, alternatively, shorter source to film distance to be used, thus considerably reducing exposure times. A further advantage, particularly with the kilocurie sources for radiography, is that the small dimensions give a lower degree of the wasteful self-absorption within the source.

A wide range of standard sources made up from 100 curies/gm material is now readily available, and some typical source dimensions are given below:—

Up to 700 mc—1 mm × 1 mm
Up to 3 c —2 mm × 2 mm
Up to 10 c —3 mm × 3 mm
Up to 20 c —4 mm × 4 mm
*1,000 c—1.25 cm × 1.6 cm
*2,000 c—1.52 cm × 2.5 cm

*These are "effective" curie strengths, allowing for self-absorption.

Nuclear Altimeter Contract

PICATINNY ARSENAL, Dover, New Jersey, the U.S. Army Ordnance Corps principal research and engineering centre for ammunition and special weapons, and the agency responsible for developing warheads for American nuclear and non-nuclear missiles, has awarded Tracerlab Inc., a contract to continue research on a nuclear altimeter. The nuclear altimeter, one of several "space age" projects being performed by Tracerlab for the Government, will differ from a conventional altimeter in that it will utilize ultra-sensitive Tracerlab developed nuclear " beta back-scatter " techniques for altitude sensing. These are the same techniques which have lately seen increased use in a variety of applications, among these material thickness measurement and process control in American industry.

In this new airborne role " beta back-scatter " will be used to sense atmospheric density at varying heights above the earth's surface. Because atmospheric density is related to height, the instrument will be able to give direct accurate indications of altitude.

Tracerlab scientists on the project are working in co-operation with the scientific staff at Picatinny Arsenal and the Aeronautical Engineering Laboratories at Massachusetts Institute of Technology.

Leader in his Field

DR. W. P. GROVE

TO the left of the main drive of the Radiochemical Centre at Amersham, surrounded by trim lawns and welcoming trees, is a quiet unpretentious house. It makes a vivid contrast to the sophisticated functional laboratory buildings that dominate the site. Yet this house and its occupant, Dr. W. P. Grove, are as much a part of the Centre as are the laboratories and the chemicals produced in them. It was here, 20 years ago, during the first year of the war, that Dr. Grove established in an outhouse a small laboratory for refining radium to be used in self-luminous paints. To-day he is head of an organization which turns out 900 different radioactive products, has customers in 60 different countries and last year sold over £1m. worth of its products.

When the war started in 1939 there was a shortage of radium in Britain. A stock of residues from the Portuguese ore autunite had been accumulated by interrupting supplies known to be on their way to an enemy country but there was nowhere in this country to process them. Previously all refined radium had been obtained mainly from Canada and Belgium. Thorium Ltd., one of the few firms, with any experience in the handling of radioactive materials, decided to set up a unit to refine these autunite residues and so supply the government with radium for luminous paint.

Kicking Heels in Scotland

To pursue this design it was necessary to find somebody to organize and operate the unit. There were very few people with suitable experience. A quietly spoken unassuming lecturer at University College who had specialized in the chemistry of rare metals and who had experience in handling radium was remembered. At the time he was kicking his heels at the Royal Naval Torpedo Establishment at Greenock. The Admiralty were only too pleased to release him, and for the young Patrick Grove himself the prospect of spending Christmas near London was more than welcome.

The next stage was to find somewhere to operate the plant. The house at Amersham was vacant and appeared to be suitable for the purpose. It was near the company's temporary headquarters at Wembley and distant enough from London to escape the possibility of continuous bombing. It was purchased.

There was an atmosphere of pioneering in the early days at Amersham. Dr. Grove and his assistants—three of whom he is proud to have with him to-day—had virtually to start from scratch in finding a method of refining the autunite residues, and much of the work was done on the crudest of apparatus—even domestic baths were pressed into service! Recalling the occasion when the first fractions of crystalline radium bromide approached purity, Dr. Grove says the appearance of the tell-tale blue glow in the darkened room at Amersham was a "thrilling event," confirming the indications of the electroscopes.

Recalling the Curies

Reading about the Curies in his youth Dr. Grove probably never expected that one day he would re-live their experience in his own laboratory. That in fact he did must have been an enormous appeal to his imagination, as it still obviously does. He has always been excited by scientific discovery and it is undoubtedly this facility, to enthuse over the pursuit of new knowledge and new techniques, that has contributed considerably to his success as director of the Radiochemical Centre. Although organized on commercial lines it is very much a scientific establishment. Research and development are as important as production. A man in charge without the scientific background and interests of Dr. Grove would have been far less successful in co-ordinating the different departments and encouraging progress.

Dr. Grove became a scientist the hard way. He left school—the Brighton, Hove and East Grammar—in 1931 when he was 17. His first job was with the Radium Institute, as a junior laboratory assistant. Here he came into contact with the rare element, radium, and for the first time in the course of his work became familiar with its properties. From the Institute he moved to May and Baker Ltd., the pharmaceutical manufacturers. He was with them for two years and during this time he continued at Birkbeck College to study chemistry.

His next job was with Johnson, Mathey & Co., with whom he gained experience in the chemistry of precious metals and, by chance in making radium needles. While here he qualified for his bachelor's degree in science and left to take up a junior lecturership in the chemistry department at University College, London. He carried out research and successfully completed a PhD thesis on the magnetic properties of salts of the platinum metals. War came and he was sent up to Scotland, but it was not until going to Amersham that he felt he was making any worthwhile contribution to the country's war effort.

Looking Ahead

Production of radium at Amersham was about 1 gm a month. Later, attention was turned to other radioactive materials and services, and it was in these activities that Dr. Grove saw the opportunity to start at the end of the war a National Radium and Radon Service to replace the system of distribution of radium appliances and radon that had operated in pre-war days.

The idea was well supported, and when the development of nuclear energy and artificial radioactive materials became evident, the plan was extended to provide a general supply service for radioactive materials of all kinds, and this became the mandate of the Radiochemical Centre when it was established under the Ministry of Supply in 1946. Later the United Kingdom Atomic Energy Authority was set up with Dr. W. P. Grove as general manager. Last year a reorganization took place to meet the increasing demand for radioisotopes and Dr. Grove was appointed director.

Veteran Traveller

Towards the end of the war, in 1944, Dr. Grove was suddenly flown to the Tube Alloys project at Montreal, Canada, to advise on the planning of a "hot" laboratory for the new site at Chalk River. Since then he has become quite a veteran traveller having visited most of the countries where Radiochemical Centre products are used. Dr. Grove enjoys this aspect of his work very much. It gives him the opportunity of meeting a great number of interesting people and to indulge in his favourite pastime of photography.

Although he lives virtually on top of his work—there are still laboratories in the outhouse and garage of the original house, though they are due to soon be dismantled—Dr. Grove manages to find time to take an active part in local affairs, including the dispensing of justice on the bench.

To the Radiochemical Centre Dr. Grove has given an efficiency and thoroughness difficult to better. Devoted to his work and loyal to his staff he is the perfect example of the successful scientist administrator. He is still young and there would appear to be a host of further opportunities ahead for him to apply his talents and capabilities.

Experts Meet

APPROXIMATELY 600 scientists from 40 countries attended the international conference on the use of radioisotopes in the physical sciences and industry at Copenhagen. The discussions covered the use of isotopes in geophysics, metallurgy and solid state physics, nuclear physics, analytical chemistry, organic chemistry and physical chemistry. There were papers on industrial applications using tracer, penetration, absorption and scattering of radiation techniques. Radioisotope production and instrumentation were also covered.

THE COPENHAGEN CONFERENCE

Review of Industrial Papers

Over 150 papers were presented at the recent International Conference on the Use of Radioisotopes in the Physical Sciences and Industry at Copenhagen, organized by the International Atomic Energy Agency with the co-operation of UNESCO. We report on some of the papers that covered the application of isotopes to industrial processes and industrial and historical research. A list of their titles is given at the end of the article for the benefit of readers.

EVEN though not everything presented at the recent international conference at Copenhagen on the Use of Radioisotopes in the Physical Sciences and Industry was absolutely new, the conference did at least serve to consolidate the establishment of isotopes as a widely versatile tool. Industrial applications discussed in the papers presented from 18 different countries ranged from thickness and wear measurements to the determination of the age of coins, from the overcoming of static in plastics to the study and inhibition of corrosion, and from the study of cosmic radiations to the autoradiographic examination of resins in textiles.

About 150 papers were read—the largest proportion of them coming from America with Britain taking a close second place. Of the 31 of United Kingdom origin quite a few came from the research laboratories of private industrial organizations.

Mr. P. Reasbeck, of Joseph Lucas Ltd., for instance, described how a tritium source of 10 to 20 curies activity was used to overcome static electricity in a coil winding machinery in which thin tissue paper was used as insulation. Two scientists from Esso Research Ltd., presented a paper on the development of a continuous plant analyser for sulphur dependent on the absorpion of X-rays produced by tritium.

Glass Measurements

J. Golden and G. W. Rowe of Tube Investments Research Laboratories discussed the use of radioactive sodium-24 in sodium silicate, the material normally used for bonding the glass powder, to measure the amount and distribution of glass coating on an extruded stainless steel hollow. In common extrusion practice the bored billet is taken from the annealing furnace and rolled in glass powder to form a protective and lubricating shine. As it rolls, a supply of glass is poured into the bore to lubricate the extrusion mandrel. Finally the billet is placed in the press behind a pad of bonded glass powder, which provides the major source of lubricant during the extrusion immediately following.

Each source of glass is traced separately by applying the mixture of radioactive sodium silicate and powdered glass to the appropriate part and measuring the activity on the extruded hollows with a Geiger counter and with autoradiographs. It was found that on an average hollow there is a reasonably uniform coating of glass about 75 microns thick over most of the surface, though the thickness decreases towards the trailing end, and there is a local reduction in thickness at a position corresponding to the original corner of the billet. The bore coating is also uniform except in this region. A small percentage of the initial coating of glass appears on the extruded hollow, contrary to earlier belief, and some remains in the container to appear on a second and even a third hollow.

Deformed Steel Studies

Another paper from Tube Investments reported on the use of radioactive inserts for studying the deformation of steel in hot rotary piercing for tube making. Iron or steel wires are activated in the pile, inserted in tubes drilled in iron or steel billets, which are then processed under normal production conditions. Careful monitoring shows that the radiation exposures and contamination of the plant are quite negligible.

On cooling, the billets are scanned in the laboratory, using a collimated scintillation counter, mounted normal to the surface of the pierced billet and isodose curves show the shape of the deformed insert normal to the tube surface. A similar scan of a section normal to the axis of the tube gives a second plot, and from a combination of the two plots a three-dimensional picture is obtained.

Resin in Textiles

Textile fabrics are often produced with anticrase and drip dry finishes by the formation of urea-fermaldehyde type resins in the material. It is thought that the uniformity of the distribution of the resin within the material has an important effect on the utility of the fabric. Courtalds Ltd., have developed a high resolution autoradiographic method of determining this distribution based on the low energy particles from tritium.

Tritiofermaldehyde was synthesized photochemically from tritium gas and carbon monoxide and combined with urea to give a resin finish to a small piece of woven fabric. Portions of the fabric mounted in a "Perspex" block, sliced into sections and polished were then used to give autoradiographs of the resin distribution. The high resolution obtained was sufficient to give the distribution of the resin within individual filaments.

Simulating the normal commercial process it was found that the resin was uniform across any filament cross section and no resin layer was observed on the filament surfaces. A deficiency of resin in the filament at the cross-over points between warp and weft yarns was noticed and shown to be due to a migration during the drying process. Treatment from alcohol solution as well as certain other abnormal treatments gave a resin deposit on the surface and a gradient of resin concentration across a filament section.

UKAEA Papers

As to be expected, the UK Atomic Energy Authority produced also some interesting papers. Autoradiographic techniques developed for the study of inclusions in steel and uranium and for an investigation into the segregation of sulphur and phosphorus in welds in stainless steel were described in one paper, and in another there was described a method measuring the volumetric flow of gas in turbulent and streamline conditions by using a small radioactive source mounted on a hinged gate. A third paper described the beryllium monitor recently developed at Harwell and now put on the commercial market.

The use of krypton-85 for detecting leaks in hermetically sealed components such as fuel elements, was described by J. F. Cameron and P. F. Berry of Wantage. The gas can be used in two distinct ways. The first is to immerse the component in the gas under controlled conditions of pressure and time and measure the amount forced in under pressure by subsequent monitoring of the radiation transmitted through the walls of the component; in the case of walls of thickness greater than 250 mgs/cm² this is a combination of bremsstrahlung and gamma-rays. In the second method some active gas is inserted before sealing and the subsequent loss of activity is a measure of the leak rate.

The method chosen depends on the dimensions of the component and its proposed use. Filling the component with even small quantities of radioactive gas is undesirable from a health point of view, although the amounts required often present a negligible hazard.

The chief limitation on the sensitivity in the first method is surface contamination due to absorption of the gas into the pores of the component material; the extent of this and the necessary corrections which have to be made were discussed in the application of the method to the detection of leaks in transistor cans. Allowing a time of 1 min for monitoring each component, leak rates of the order of 10^{-13} cc's (NTP)/sec were detectable and correlation of results achieved by this method with the manufacturers' tests for expected componant life were made and the agreement was satisfactory.

Generally speaking the larger the component the lower the sensitivity, so that to achieve 10^{-12} co's (NTP)/sec, with thermionic valves it would be necessary to devote an hour to each measurement. Prefilling of the component with active gas before sealing has the advantage that, in addition to allowing an evacuation test and subsequent monitoring of the egressing gas to evaluate the leak rate with a sensitivity comparable with the helium mass spectrometer, a long-term monitoring of the contents of the component is possible. This eliminates the possibility of a leak closing up temporarily during the short term pressure or vacuum test and provides an integrated value to the leak which is more useful.

Wear Measurements

Several papers covered the use of isotopes in wear measurements. Two were from the National Engineering Laboratory, Glasgow. In one a survey was made of the various applications that had been studied there. The other dealt with an investigation of the reaction of metals with sulphur and phosphorus compounds. The anti-wear action of such compounds which are usually added to gear oils depends on chemical reactions with the metallic surfaces of the gears. These reactions occur both at the bulk oil temperature (approximately 100°C.) and during high temperatures (approximately 600°C.) of short duration when the gear teeth come into contact under lead.

The temperature flashes were simulated in an apparatus in which short pulses of electric current were used to heat metal wires immersed in mineral oil containing sulphur-35 and phosphorus-32 labelled compounds in solution. The radioactivity acquired by the wires was

then measured. The extent of the reactions was determined as a function of temperature and time and the results were interpreted in terms of conventional kinetic laws.

A study was made of the modification of the reaction rates by the presence of other compounds in the solution. The effect of pre-formed surface films containing sulphur, phosphorus, chlorine and/or oxygen was also determined. In explaining the results the structure of the materials used and the diffusion processes whereby the reactions occur beyond the initial stages were considered.

French scientists described their experiences with radioisotopes for studying the wear of refractory linings, while from America came a report on the results of the application of isotopes in investigating lubrication and wear in large diesel engines. In Japan use of isotopes has been made to examine the wear of tools used for shearing sheet metals and the Czechs have made use of them for controlling the wear of suspension bearings of large turbogenerators. The Department of Mines and Technical Surveys, Canada, have used them for measuring the wear of cast grinding balls.

Properties of Oils

Two Soviet scientists discussed laboratory procedures for investigating the operative properties of oils with additives, and ascertaining how these act. They had devised a tracer method for investigating electrokinetic processes and sedimentation in oils with additives containing labelled carbon black. Their paper described results obtained from experiments using this method.

The authors defined precisely the essential difference between the requirements for the chemical compounds respectively constituting anti-corrosive and anti-friction additives. That difference is the basis of a complex method of investigating multi-component additives having a high anti-friction efficiency but no corrosive action. The method employs radiometric determination of the corrosive effect of oils containing anti-friction additives during interaction with radioactive copper, selection of the most corrosive anti-friction components, choice of effective anti-corrosive components to go with these, and determination with the four-ball apparatus of the anti-friction efficiency of the mixture so chosen.

Battery Shelf Life

One of the most interesting industrial applications described at the conference was that of the investigation of the storage capacity of silver-zinc batteries. It was generally considered according to the author of the paper, Tivadar Palagyi, of Budapest, that the shelf life of silver zinc storage batteries was not influenced by whether it was in a charged or discharged state during storage. He found, however, that this was in contradiction to results obtained during investigations on the cell mechanism. To decide the question he carried out some radioactive tracer experiments on cells manufactured in the laboratory and having a nominal capacity of 10 amp/hr.

It was assumed that a conclusion concerning the more advantageous storage method could be drawn from the contamination with the isotope of the electrodes of the cells stored in charged and discharged condition, respectively. Altogether 32 cells were built; 16 cells with a negative electrode labelled with zinc-65 and 16 cells with a positive electrode labelled with silver-110. Both isotopes were electrolytically deposited on the electrodes.

After filling the cells with electrolyte and after three charging and discharging processes, eight cells from each of the Zn65 and Ag110 labelled groups were stored in a charged and eight in a discharged state. From each of the resulting four cell groups two cells were opened after one months' storage and two cells were opened after two, three, and six month's storage, respectively. The activity of the electrodes was measured with a cylindrical GM-tube and the electrodes were replaced into the casing with the order unchanged. After the reassembly and filling of the cell with fresh electrolyte, the cycling for determining the cell life was started.

Experiments proved that while storing cells with a labelled negative electrode, both the positive and negative electrodes dissolve to a certain degree. The unlabelled electrodes of cells stored in a charged state were contaminated in a higher degree and, after storage, these cells yielded less cycles than the cells stored in a discharged static. From this fact, it can be inferred that storage in the discharged state is more favourable than in the charged state.

Tracing Silt

The National Hydraulics Laboratory, of France, in collaboration with the Saclay Nuclear Study Centre, has for several years been devising equipment and techniques for the study of sediment movements by the radioactive tracer method and is now endeavouring to develop a really quantitative method of research. Two river experiments were recently made, the first a study of shingle drifting in the Rhone, the second a study of sand movement in the Niger. The latter experiment was matched by identical experiments carried out on a scale model of the River Niger which the Chatou Laboratory has at its disposal. The experiments used manganese-56 radiation obtained by direct activation of crushed apricot stone, this representing in the scale model the natural sediment of the Niger bed. Results of the experiments so far were described by P. Jaffry and M. Heuzel.

Papers on tracing water flow also came from America, Russia and the Netherlands. Koninklijke Shell Laboratoties, at Amsterdam, have been studying the flow of water in an oil reservoir by means of tritium. Tritiated water was injected into the well and then the tritium in surrounding wells determined. Similar experiments have also been carried out by the Russians.

From many of the Russian papers it would appear that their scientists are quite some way behind British engineers in the application of isotopes particularly for industrial purposes. There were papers, for instance, on thickness measurement, which has been established practice in this country for some time now in some firms, and another on the control of flotation processes. They also appear to find the use of carbon-14 for dating geological and archaeological objects fairly novel.

Historical Research

On the historical side, the paper from Poland on the use of gamma radiography to determine the method of bronze casting used in the 12th century was particularly interesting. Students of medieval craftsmanship were interested in finding out how the great double doors of the Gniezno cathedral were fabricated. They wanted to know whether the intricate sculptured figures on the face of the door had been cast together or whether they had been made in parts. They also wanted to find out how the liquid metal had been carried to the casting mould. Radiologists themselves were interested in the degree to which radiographic investigations could solve such problems.

Already in 1954, on the basis of exact external examination and partial radiographic investigations using X-rays, it was confirmed that the right wing of the door was composed of parts cast separately and bound together by means of hard soldering. These investigations did not decide, however, the manner of construction of the left wing, the quantity of parts composing each leaf and the way in which these parts were cast. About 100 radiographs, each measuring about 9½ in. × 12 in., were taken of the left wing using caesium-137.

Also of Interest

Purity control in the manufacture of silicon was the subject of a Japanese paper and there were one or two contributions on sampling impurities in iron and other metals. The Laboratory of Atomic and Solid State Physics at Cornell University sent in a paper on the use of calcium-45 for studying imperfections in alkali halide crystals.

Among other interesting general papers worth mentioning are the survey of applications developed in Australia, the report on results obtained by Russians in using isotopes for prospecting for coal and ore deposits, and the suggestions for uses of isotopes in the rubber industry.

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(*Continued on page 493*)

DETERMINING CYLINDER WEAR

by W. C. Arnold, V. T. Stonehocker, Fairbanks, Morse & Co.

Irradiation of selected sections of large engine parts now allows the radiotracer method of determining wear to be extended to large engine cylinders. Long used for piston-ring wear measurements, the techniques now provide accurate results quickly and economically for the more important cylinder wear.

ALTHOUGH radiotracer techniques have been used for some years to measure piston-ring wear, until recently it was not possible to apply this method to larger parts, such as cylinders. Unfortunately, ring wear data seems to bear little correlation to wear rates of cylinder liners — and cylinder wear is more important than ring wear because cylinders cost more to replace.

With the new techniques, the effect on cylinder wear of starting, idling, and cold temperature operation; sudden cold changes; speed; torque; and other variables can easily be determined. Simultaneous data can be obtained on rings and cylinders and other wearing parts of the engine through the use of different isotopes and pulse height analysis. Local areas can be monitored through selective irradiation of the cylinder in conjunction with the pulse height analysis.

There are three principal stages in the application of this method:—

(1) Irradiation of selected areas of the cylinder liner;

(2) Installation of the radioactive liner in a diesel engine;

(3) Qualitative and quantitative determinations of cylinder wear.

The cylinder liner selected for irradiation in an experimental run-through was 42 in. long, weighed 160 lb and was designed for a 8⅛ × 10 in. opposed-piston diesel engine built by Fairbanks, Morse & Co. The liner was irradiated at the inner-dead-centre position of the compression-ring travel because this is the area of maximum wear in these particular cylinders.

Cadmium Shield

This was accomplished by providing the liner with an external shield of cadmium and an internal shield of boral alloy. A 1½ in. wide unshielded target band is visible at the position corresponding to the contact zone of the top two compression rings of the lower piston when at its inner-dead-centre position. The wires visible about the circumference of that zone are aluminium-cobalt dosimeter wires used for recording the integrated thermal neutron flux falling on the target zone.

The shielded cylinder liner was installed in a watertight aluminium capsule. The aluminium tube, later removed, was used to pressurize the capsule with helium during irradiation. This gas prevented water from entering the capsule if it leaked during irradiation. Since helium does not become radioactive, the hazard to reactor personnel in case of capsule failure was minimized.

The helium-pressurized cylinder-liner capsule was irradiated for four weeks in a pool type reactor.

Following irradiation the liner was placed in a large diameter lead shield and de-encapsulated. Next, a small quantity of cylinder-liner metal filings radioactivated in shielded and unshielded areas of the liner were analyzed.

Irradiation

Substantial amounts of 300-day half-life Mn54 were evenly distributed in both shielded and unshielded zones. That radioisotope was produced by fast or high-energy-neutron activation of Fe54. The amount of 45-day half-life Fe59 and 27-day half-life Cr51 produced in the unshielded target zone was much less than had been anticipated because of the effect of neutron perturbation (a reduction in the thermal-energy flux reaching the unshielded target, because of the large amounts of cadmium and boron in the vicinity). In fact, perturbation resulted in about one-twentieth the anticipated thermal neutron activation of target zone metal.

The attempt to activate a liner in a small, specific zone to a comparatively high level of specific radioactivity was successful to a limited extent. With the employment of elaborate radiation detection equipment during analysis it would have been possible to discriminate wear occurring in that zone. However, it was not attempted in this programme.

Mn54 was produced in useful quantities in the entire lower half of the liner. The 300-day half-life of that radioisotope resulted in a liner with a useful radioactive life of years, compared with that of months normally present in piston rings, which are normally activated in a manner that produces shorter-lived Fe59 and Cr51.

The desirability for capsule rotation was confirmed by the evenly radioactivated cylinder liner.

After being irradiated the cylinder liner had to be installed in the test engine. The Battelle Memorial Institute were responsible for developing handling techniques which ensured the minimum exposure of staff to radiation hazards. A careful evaluation was made of all operations that would be involved and this interpreted in terms of the hazards presented. Handling and installation procedures were then developed.

Four months prior to the installation, a Battelle representative visited the Beloit works of Fairbanks, Morse to observe all operations related to liner production, installation, and engine build-up.

After cylinder-liner irradiation it was possible to evaluate the radiation hazard that would exist during each operation. It was calculated that the total radiation dose received during pre-installation handling would range from 50 to 100 milliroentgens. It was estimated that an additional total exposure of about 1,000 mr would be acquired during liner installation and engine build-up. That dose would be distributed among six to eight operators.

No Remote Handling

It was apparent from these estimates that no single operator would receive the maximum permissible exposure of 300 mr/week if care were taken to rotate personnel for these operations. Because of the adeptness demonstrated by each operator for performing his individual task, the use of remote handling equipment was considered unnecessary. While remote handling would serve to decrease the radiation dosage rate, the resultant increase in time required for completing a remote-handling operation would result in an overall increase in cumulative dosage.

The specially crated lead-shielded liner was transported from Columbus, Ohio, to Beloit by truck. Operations involving jacketing, water testing, honing and bore checking were all performed by production personnel at the normal production station used for each operation. During these operations the radiation hazard created in the area of the liner was evaluated with radiation survey meters. All personnel concerned with liner handling in any way were provided with radiation-sensitive film badges for recording cumulative dosage, and direct-reading pocket dosimeters. Accumulated radiation doses were determined intermittently from the dosimeters. All pre-installation handling operations were completed in 3 hours, and a maximum radiation dose of 80 mr was measured by the film badge for one operator. Other personnel received negligible dosages. Care was taken to ensure the freedom of all areas and equipment from radioactive contamination.

Installation of the radioactive liner and engine build-up were completed in three 8-hour shifts. Two operators plus a supervisor were used for each shift. Film badges, dosimeters, and radiation-detection instruments were employed as safety measures. A Battelle representative was present at all times to supervise the handling of the radioactive liner and to make certain that radiation safety measures were being properly executed. Radiation doses measured with pocket dosimeters ranged from 35 to 80 mr. No one involved in engine build-up received more than the permissible dose.

Film Badges Provided

After a normal build-up the engine and its immediate working area were evaluated as a radiation hazard. A suitable area was roped off about the engine at a sufficient distance to limit the radiation intensity beyond the designated zone to less than 2 mr/hr. Signs warning of the radiation hazard were posted to designate that zone. All personnel permitted inside the posted area were provided with either film badges or pocket dosimeters. A radiation intensity of 20 mr/hr was measured at the closest approach point of a man's torso to the installed liner, and an intensity of 60 mr/hr was measured at the closest approach point of a man's hands to the installed liner. The maximum dosage received by an operator during all the operation of the engine was 60 mr/week.

Radioassay techniques were developed to determine cylinder wear both qualitatively and quantitatively. These radioassay procedures were developed for analyzing wear products distributed in both the lubricating oil and exhaust gas stream. Throughout the experimental programme lubricating oil and exhaust gas samples were simultaneously collected for analysis at 6-16 hour intervals.

Actual Wear Compared

The precision of the radioactive-tracer method was determined by comparing tracer-measured gross wear following each engine test with actual wear as determined from measurements using a bore-gauge micrometer. This was determined by measuring four diameters of the cylinder at eight elevations before and after each test. These readings

were averaged to determine the diametrical increase at each elevation and thereby the total volume of material.

Two methods were investigated for the radioassay of lubricating oil samples. The first method involved various techniques for removing and concentrating radioactive debris from lube oil samples. An advantage of this procedure was the inherently high efficiency of gamma-ray detectors for concentrated radioactive debris. Only limited success was achieved in developing a suitable technique for concentrating wear product debris because of an inability to perform uniform separation of a high fraction of the radioactive debris from lube oil samples.

Special Counting

The second, and selected, method was the direct analysis of untreated lube oil samples. Special counting techniques conducive to extreme instrument stability, and counting procedures resulting in a maximum statistical counting efficiency were employed for direct lube oil sample analysis. The analysis of litre-volume samples with an immersion scintillation crystal-type detector, coupled with a precision scaler were employed for lube oil analysis.

An exhaust gas sampler designed for the isokinetic sampling of 0.4 per cent. of the exhaust gas stream of the test engine was installed in the exhaust system. Since the volume of exhaust filtered was small, the duration of operation of the system varied, depending on the actual debris carried by the exhaust gases. Debris collected on fibre glass filter mats was reduced chemically for assaying in the well counter. It should be pointed out that this chemical separation procedure was necessitated by the capacity of existing equipment. To handle the large number of samples expected during the utilization of this technique, a scintillation well counter was provided with a large dimension crystal to permit direct counting of the exhaust filter mats.

Standards Produced

Cylinder-liner metal fittings radioactivated in both shielded and unshielded zones of the liner were processed for use as analytical standards. The properties of those standards were such that they would be subject to the same radioactive decay rates as was the cylinder-liner metal itself. These standards were radioassayed at periods corresponding to sample analysis, and used to compensate for the decay of the radioactive liner and for slight variations in instrument efficiency.

The actual wear could be calculated from the engine lube oil consumption rate and the assay information. These procedures were used in determining the data.

New C14 Standard

Mr. W. F. Marlow (*right*) and Mr. R. W. Medlock of the National Bureau of Standards are shown filling and sealing ampoules with the benzoic acid-7-C14 standard (in centre flask) for liquid-scintillation counters

THE National Bureau of Standards has prepared a new carbon-14 standard sample to meet the need created by the increased use of liquid-scintillation counters, particularly in biochemical and medical studies. The solvents most often used in these counters are toluene and xylene; the standard used in their calibration must therefore be soluble in and compatible with these compounds. To fulfill this requirement, Mr. W. F. Marlow and Mr. R. W. Medlock of the Bureau's radioactivity laboratory used benzoic acid-7-C14 dissolved in toluene for the new standard[1].

In the past few years, liquid-scintillation counting systems have become increasingly accurate and reliable, while their cost has greatly decreased. The sample of material to be counted by this method is more easily prepared than for most other methods, and since it is dissolved directly in the solution, the counting efficiency is usually much greater, especially for low-energy radiations of C14.

The sample of benzoic acid-7-C14 in toluene was standardized by quantitative oxidation of the benzoic acid and toluene. The carbon dioxide produced was collected and the level of radioactivity of this carbon dioxide was compared, in an ionization chamber, with the radioactivity of carbon dioxide prepared quantitatively from the national sodium carbonate-C14 standard.

Previous work[2] has shown that $C14O_2$ and $C12O_2$ may be evolved at different rates during oxidation of organic compounds either by wet combustion or by burning in an oxygen stream. The possibility of error due to this isotope effect was avoided by burning the sample in a modified Paar oxygen bomb to obtain complete oxidation.

The new C14 standard sample may be obtained from the Radioactivity Section, National Bureau of Standards, Washington 25, D.C. for $27.00[3].

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[1]For further information, see "A Carbon-14 Beta-ray Standard, Benzoic Acid-7-C14 in Toluene, for Liquid-Scintillation Counters," by MARLOW, W. F., and MEDLOCK, R.W., *J Research* NBS **64A,** 143(1960).

[2]" Errors of Combustion of Compounds for C14 Analysis," by ARMSTRONG, W. D., SINGER, L., ZBARSKY, S. H., and DUNSHEE, B., *Science* **112,** 531 (1950).

[3]A complete listing of standard samples is contained in Standard Materials, NBS Circular 552 (third edition), which may be obtained by writing to the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (35 cents).

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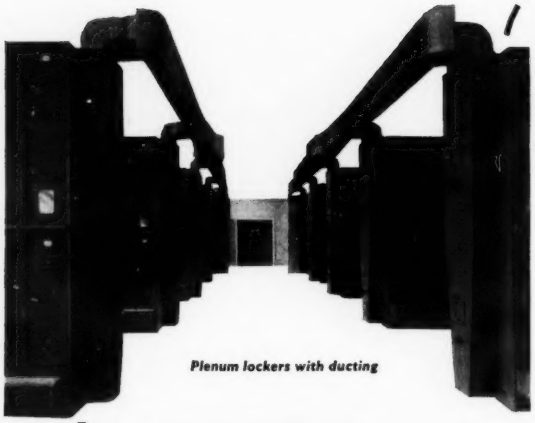

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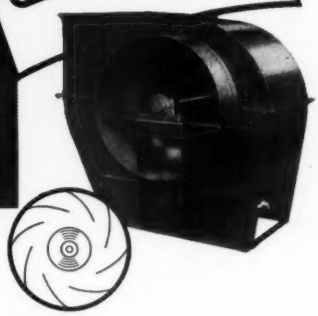

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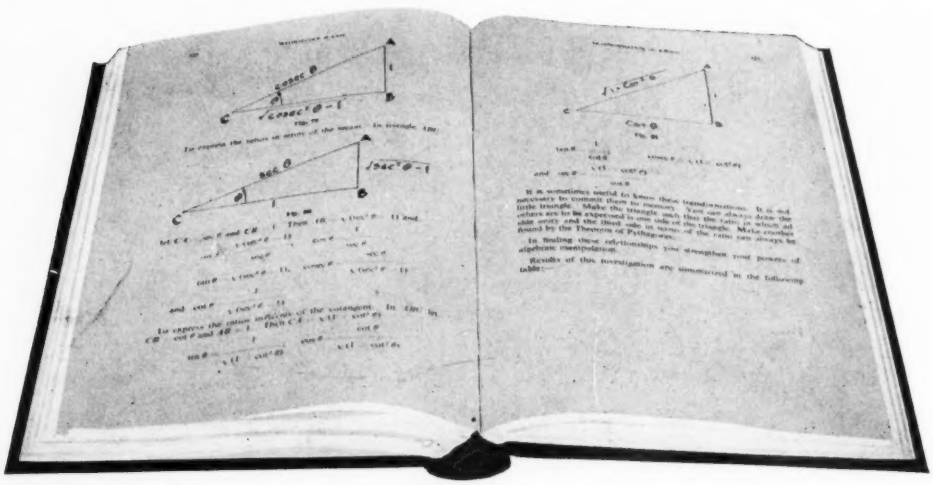

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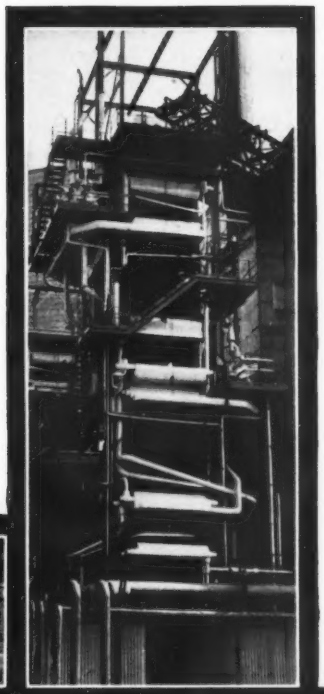

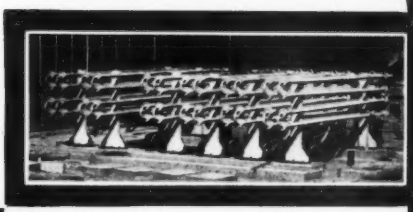

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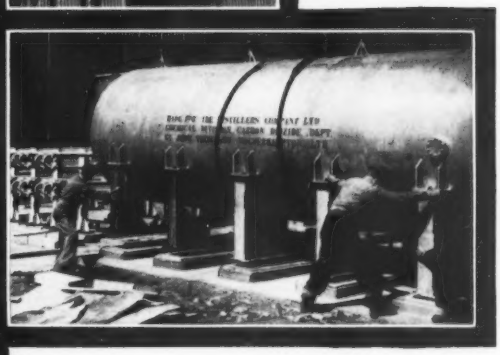

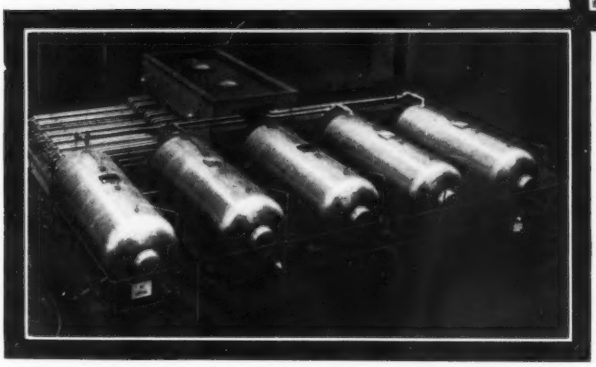

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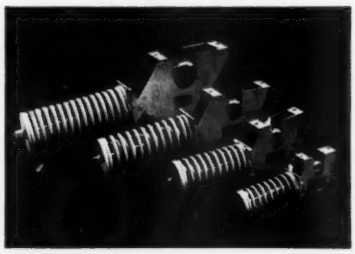

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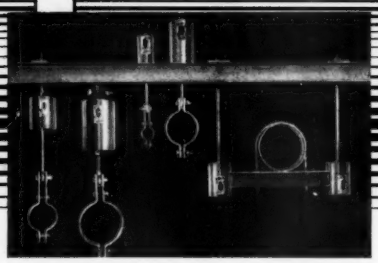

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